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AUTHOR Swope, William M.; And Others
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ABSTRACT

Computer services provided to the Navy Computer Managed Instruction (CMI) system and numerous non-CMI users are the focus of this report of a study designed to (1) analyze the response time, interruptions, and availability of the CMI system; (2) determine the impact of the non-CMI users on the ability of the system to respond to CMI requirements; and (3) identify the hardware/software limitations of the present CMI system and explore possible improvements. This report is designed for use in maintaining CMI system reliability, and provides data to support expansion of the system capability to serve an anticipated increase in the student load. An introduction is followed by a review and summary of the CMI performance data from March to October 1981; a description of the hardware and software configuration and limitations of the present system; a discussion of the requirements and problems associated with non-CMI users being served by the system; and an analysis of the relationship between computer downtime and training time to determine whether unavailability extends training time. A summary and recommendations conclude the report, and detailed information on various performance statistics is appended. (Author/LMM)

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Technical Report 119

ANALYSIS OF FACTORS AFFECTING THE PERFORMANCE OF THE NAVY'S COMPUTER MANAGED INSTRUCTIONAL SYSTEM

William M. Swope
James M. Corey
Richard M. Evans
Charles L. Morris

Training Analysis and Evaluation Group

April 1982

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Alfred F. Smode

ALFRED F. SMODE, Ph.D., Director
Training Analysis and Evaluation Group

W. L. Maloy

W. L. MALOY, Ed.D.
Deputy Chief of Naval Education and Training for Educational Development and Research and Development

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The Management Information and Instructional Systems Activity at Memphis currently provides computer services to the Navy Computer Managed Instruction (CMI) system and numerous non-CMI users.

This report presents information which can be used to maintain (CMI) system reliability and provides data to support expanding the system

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capability to serve an anticipated increase in the student load.

The objectives of the study were to:

- analyze the response time, interruptions, and availability of the CMI system
- determine the impact of the non-CMI users on the ability of the system to respond to CMI requirements
- identify the hardware/software limitations of the present CMI system and explore possible improvements
- analyze the relationship between computer downtime and lost training time to see if computer unavailability extends training time.

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SECTION I

INTRODUCTION

The Management Information and Instructional Systems Activity (MIISA) at Memphis currently provides computer services to the Navy Computer Managed Instruction (CMI) system and to numerous non-CMI users. There is concern about the impact the non-CMI users are having on the ability of the system to meet the CMI requirements as well as the effect of computer downtime on training time. There is also a need to identify other factors which degrade, or have the potential to degrade, CMI system performance. Accordingly, the Chief of Naval Education and Training (CNET) tasked the Training Analysis and Evaluation Group (TAEG) to identify and evaluate those factors which adversely impact CMI response time.[1]

PURPOSE OF THIS STUDY

The purpose of this study was to provide information which could be used to maintain system reliabiity as the CMI processing requirements increase and to provide data to support expanding the CMI system capability to serve an anticipated increase in the student load.

Specific objectives of the study were to:

- analyze the response time, interruptions, and availability of the CMI system for the period between March and October 1981
- identify the non-CMI users, summarize the requirements these users are placing on the system, and determine the impact these users are having on the ability of the system to respond to CMI requirements
- identify the hardware/software limitations of the present CMI system and explore the possibility for improving both hardware and software to increase efficiency, capability, and reliability of the CMI system
- analyze the relationship between computer downtime and lost training time to see if computer unavailability extends training time.

APPROACH

An analytical study was done which utilized data obtained from the following sources:

- Computer terminal user reports were collected weekly between March to October 1981 and served as one basis for assessing the CMI system performance.

[1]CNET tasking ltr of 15 May 1981.

- Periodic MIISA reports dealing with system component failures, frequency and type of transactions, non-CMI user requirements, and processing time provided the data from which conclusions were drawn about system capability and availability.

- Information on system hardware/software configuration was obtained from extensive interviews with MIISA system managers and support personnel including representatives from the Honeywell Corporation.

- Additional data were collected from interviews with school personnel concerning the handling of students during computer downtime and problems the schools were experiencing with the central CMI system.

Analyses of the above data provided the basis for the conclusions and recommendations of this study.

ORGANIZATION OF THIS REPORT

In addition to this introduction, this report contains five additional sections and one appendix. Section II reviews and summarizes the CMI performance data from March to October 1981. Section III discusses the hardware and software configuration and limitations of the present CMI system. Section IV discusses the requirements and problems associated with non-CMI users being served by the CMI system. Section V includes an analysis of the relationship between computer downtime and training time. Section VI presents the summary and recommendations. The appendix contains detailed information on various performance statistics.

SECTION II

ANALYSIS OF CMI PERFORMANCE (MARCH THROUGH OCTOBER 1981)

Beginning in March 1981 performance statistics were collected for each shift at the CMI locations (Memphis, San Diego, Great Lakes, and Orlando). Each week all four sites forwarded a CMI Computer Terminal Users Report to CNTECHTRA, MIISA, and CNET. Variables for which data were collected included CMI response time, number of interruptions, number of minutes the system was down during the shift, and the percentage of time the CMI system was available to the students. This section of the report summarizes the performance data for the CMI system between March and October 1981. The data for each variable are summarized for each of the four sites, seven courses, and two shifts. An observation consists of a measure of a variable taken for a given day, shift, course, and location.

RESPONSE TIME

The response time is measured (in seconds) from the time a test answer sheet is ejected from the OPSCAN reader until the first character of print appears on the corresponding learning guide at the terminet. Response time is sampled for the first 10 minutes of each hour, beginning with the second hour and ending with the sixth hour of each shift. The response time does not include the time required to print the learning guide which varies depending upon the length of the guide. The procedure for sampling response data was specified by CNTECHTRA.

Figure 1 shows the monthly distribution of response times for all observations between March and October 1981. The average response time has steadily decreased since the second quarter. By October, response time was averaging less than three seconds per transaction. The average response time at Great Lakes is slightly higher (approximately 4 seconds) and the remaining sites are averaging 2 seconds or less (figure 2). Approximately 62 percent of the measured response times were 3 seconds or less. (See figure A-1 in the appendix.)

The response times by day of week were considerably higher for Mondays during the March to June period. Since then, differences among the days of week have diminished and by October no significant differences existed (figure 3). Response times by day of week and month are illustrated in appendix figure A-2.

Fewer than two percent of the observations had response times exceeding 25 seconds, and fewer than 15 percent of the observations had times exceeding 10 seconds. Most of the longer response times occurred during the early part of the study period (figure 4).

The response time for the Propulsion Engineering (PE) CMI course at Great Lakes was slightly slower than for the remaining six courses which are on the CMI system (figure 5). This slower response time can be attributed to differences in course curriculum. The higher response time for the PE course causes the mean response time at Great Lakes to be slightly higher

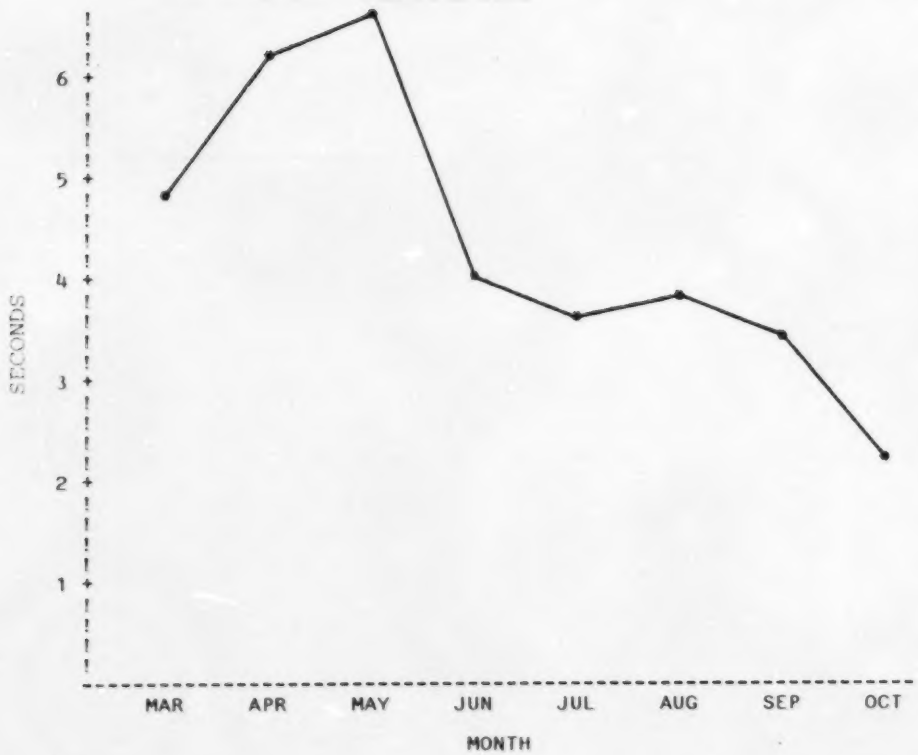

Figure 1. Mean CMI Response Times (All Observations)

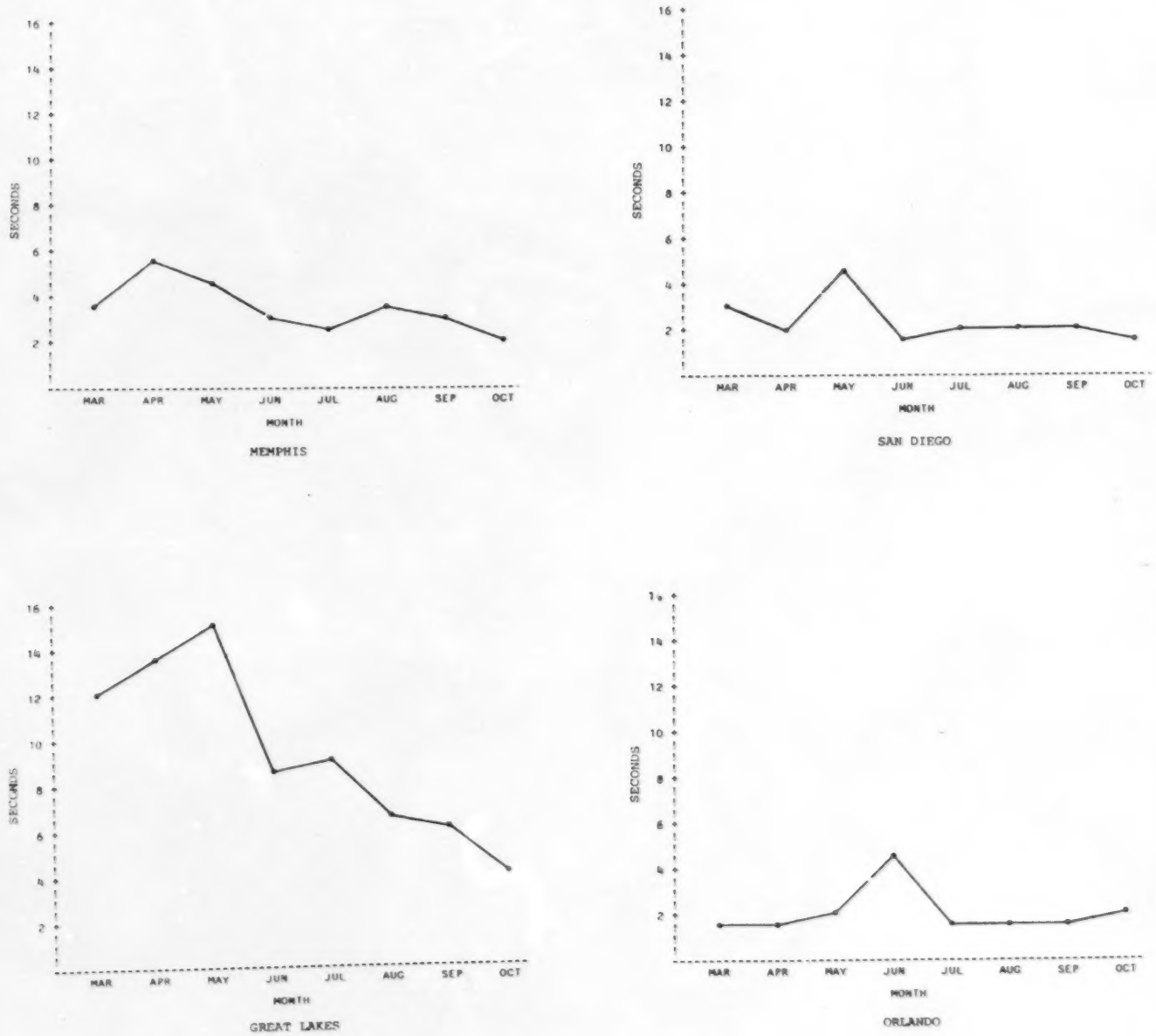

Figure 2. Mean CMI Response Times by Location

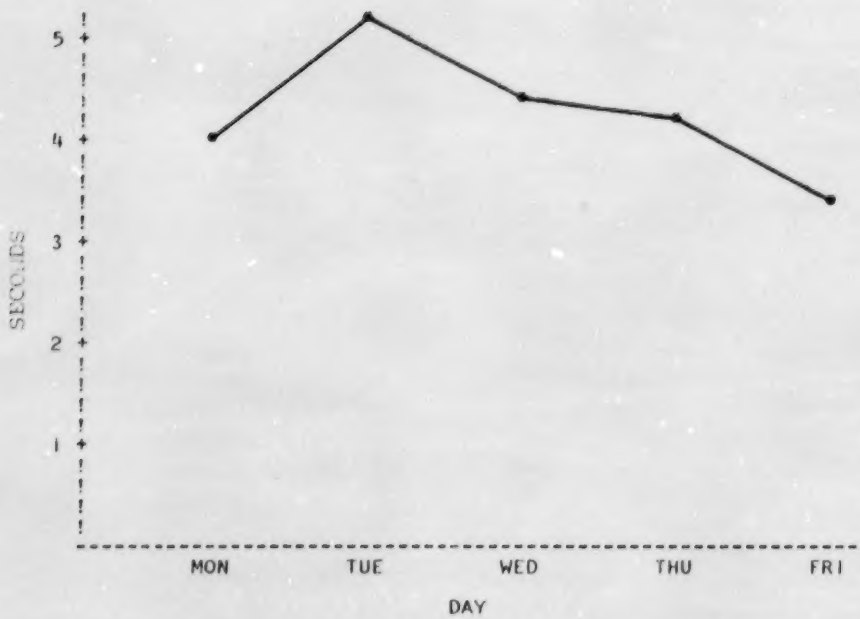

Figure 3. Mean CMI Response Times by Day of Week (All Observations)

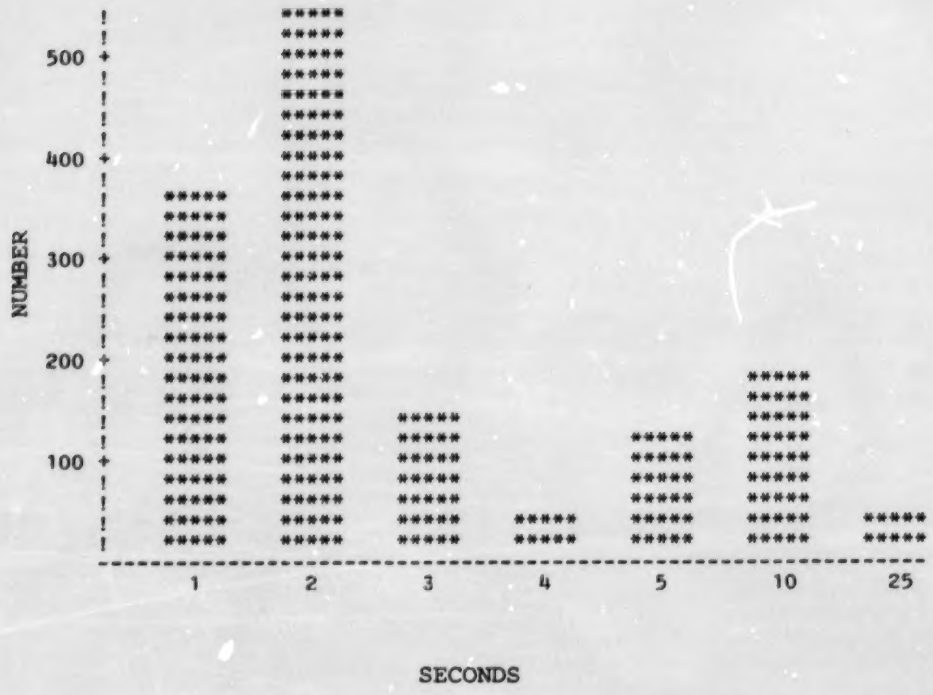

Figure 4. Histogram of Mean Response Times for All Observations

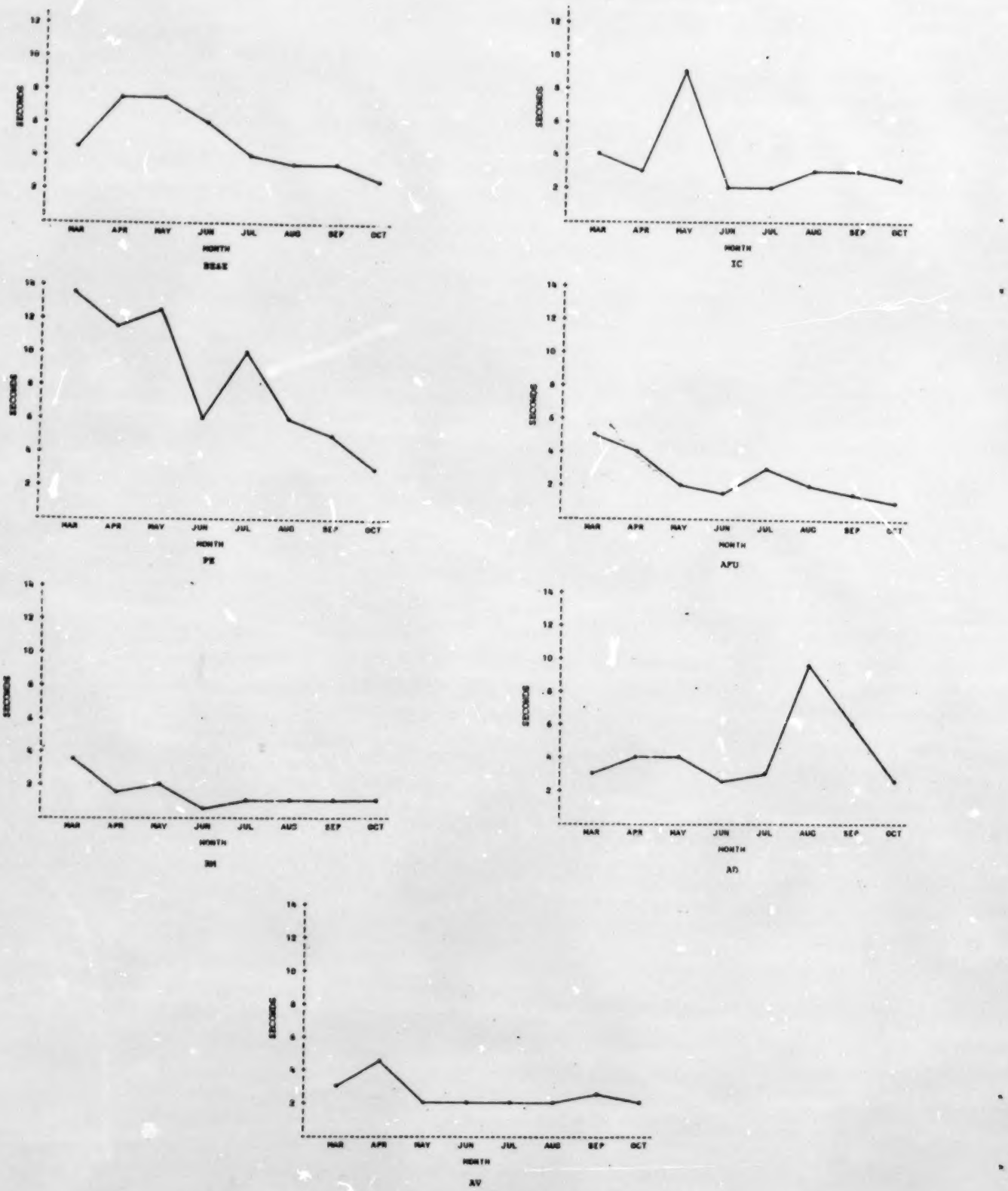

Figure 5. Mean CMI Response Times by Courses

than the other three locations. There were no significant differences in response times by day of week or shift (appendix figure A-3).

Response time is, at present, very fast but it is evident that future system expansion will eventually lead to degradation of system response time. Because of the complex interrelationships of the system involving time of day, hardware and software limitations, non-CMI user requirements, and file maintenance and access procedures, it is difficult to ascertain, with any degree of confidence, where the system will degrade. An actual scenario or simulation based scenario must be analyzed to determine where "bottlenecks" occur and to identify factors which contribute to slow response time.

INTERRUPTIONS AND DOWNTIME

The number of interruptions for each month between March and October are shown in figure 6. The interruptions are summed for each location and course. When the CPU is down at Memphis there will be an interruption at each course and location. The number of interruptions by day of week did not differ significantly. (See figure A-4 in the appendix.) The number of interruptions by site is illustrated in figure 7.

The downtime for each interruption was not recorded so it was not possible to construct a precise distribution of mean downtimes. The information which was available was the total downtime and number of interruptions for each day. The mean downtimes used in this study were estimated by dividing the total downtime for each day by the number of interruptions in that day. The mean downtime during the study period showed a general downward trend. By the end of October, the mean downtime was estimated to be between 12 and 18 minutes per occurrence (figure 8). This represents considerable improvement from the high in March which exceeded 30 minutes. The mean downtimes by location are shown in figure 9. Figure 10 is a histogram of the downtimes and again demonstrates that most downtimes were approximately 10 minutes or less. Figure A-5 in the appendix shows the distribution of downtime duration for day of week. No significant differences were observed among the locations or for the day of week.

The response time, number of interruptions, and average duration of downtime all interact to determine the total time the CMI system is unavailable to the student. The reported downtime is intended to measure or track the entire time during each shift the system was not available for use. However, the method used for recording the downtime depends upon the staff or students placing a demand on the system, both when the system goes down and when it resumes operation. If there are no demands for service on the system when it goes down, then the actual downtime may occur at some point prior to the point at which the observation was taken. Therefore, under certain conditions the actual observed downtime could be shorter than the actual time the system was down. Similarly, if the system resumed operation and there was no demand for service then the system could have been back in operation before the observation was taken. This would tend to lengthen the reported downtime. Deficiencies in reported data should, however, not be

serious and the following data on total downtime is submitted recognizing the above potential difficulty.

The total downtime shown for each month in figure 11 is the total amount of time that CMI services were not available for all courses during the month. Downtime could occur at a site even though the central CPU was operating. If the CPU at Memphis were to fail, curtailing service to all courses and sites, then the total downtime as illustrated in figure 11 would be determined by adding the observed downtime for each course at each site. For example, two courses at each of two sites will result in total downtime of 240 minutes when the CPU goes down for 60 minutes. There was a significant downward trend in the number of minutes the system was unavailable from March to October 1981. During October the cumulative downtime for all courses at all sites was less than 2,000 minutes out of a total of approximately 100,000 minutes for the month. The Basic Electricity and Electronics (BE&E) course had the highest number of minutes of nonavailability because BE&E is taught at all four CMI locations. The total downtime by day of week and course is shown in figures A-6 and A-7 in the appendix.

SYSTEM AVAILABILITY

The total downtime, measured at each location, can result from any number of causes. Although the entire system will be down when the CPU at Memphis is down, there are other failures which result in specific locations being down. Figure A-8 in the appendix shows the downtime for each location. Assuming that the minimum downtime in each month at the four locations represents the maximum amount that the CPU at Memphis could have been down, it is apparent that failures which occur at Memphis and cause the whole system to go down have been relatively low during the latter part of the study period. Actually, the failure rate of the CPU will be significantly lower than the above minimum times since many of the failures as observed at the site could be attributed to site problems. Failure of the central computer was not a significant problem during the study period.

The percent of nonavailablity is computed by subtracting the number of minutes the system is down during a shift from the total minutes available in the shift during the day and dividing the results by the total minutes available in the shift.[3]

Figure 12 shows the percent of time that the system was not available, averaged for all sites, during the period March to October 1981. Since March, monthly downtime has averaged less than 5 percent. Total system availability was very high during the period, and there was no evidence that system downtime was a problem. System availability by location and day of week at each location is presented in figures A-9 and A-10 in the appendix. System availability appears to be slightly higher at Memphis and Great Lakes than at Orlando and San Diego although the differences are not great. There are no significant differences in availability among the days of the week.

[3] CNTECHTRA msg 111848Z Mar 1981.

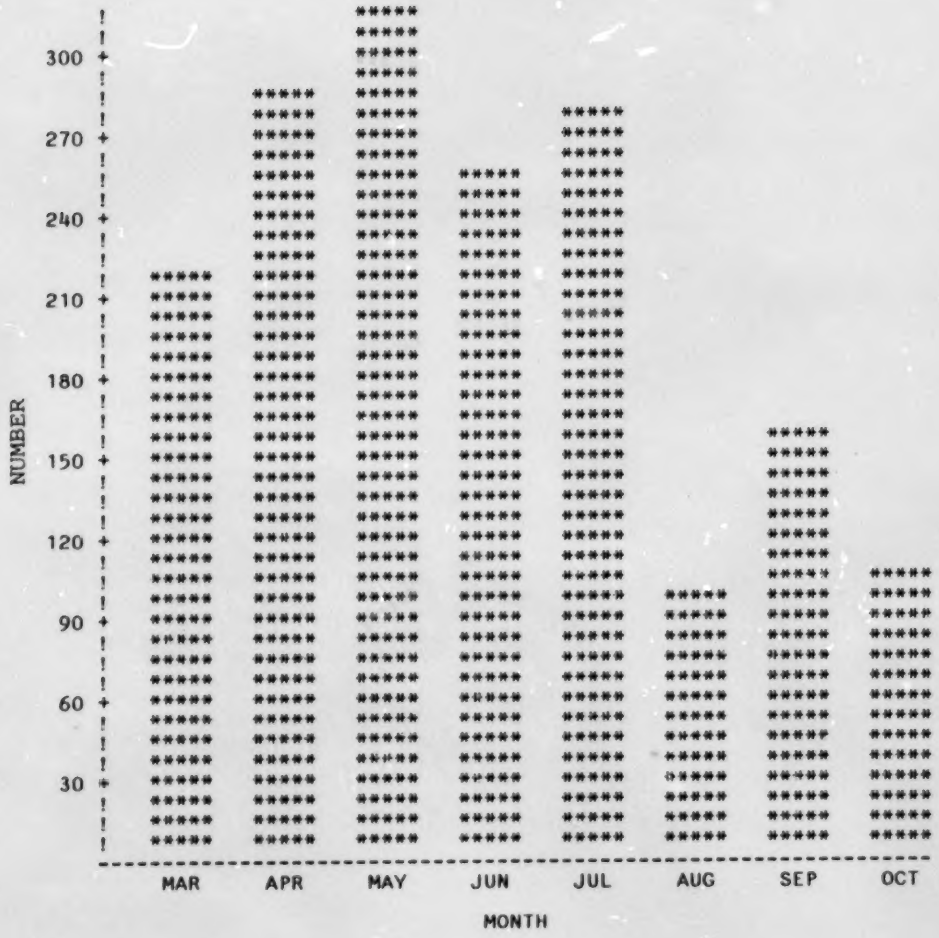

Figure 6. Total Interruptions for All Courses

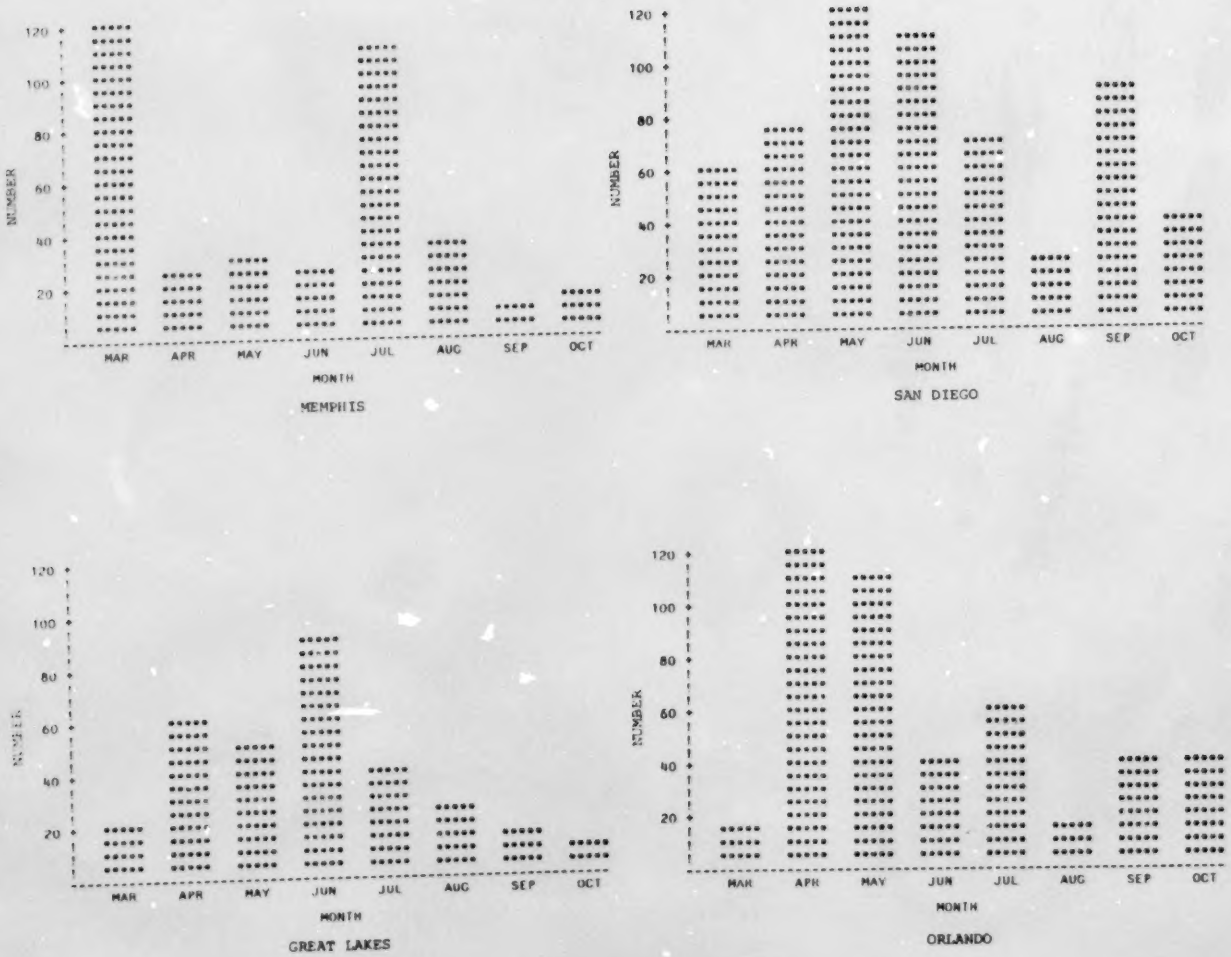

Figure 7. Total Interruptions by Location

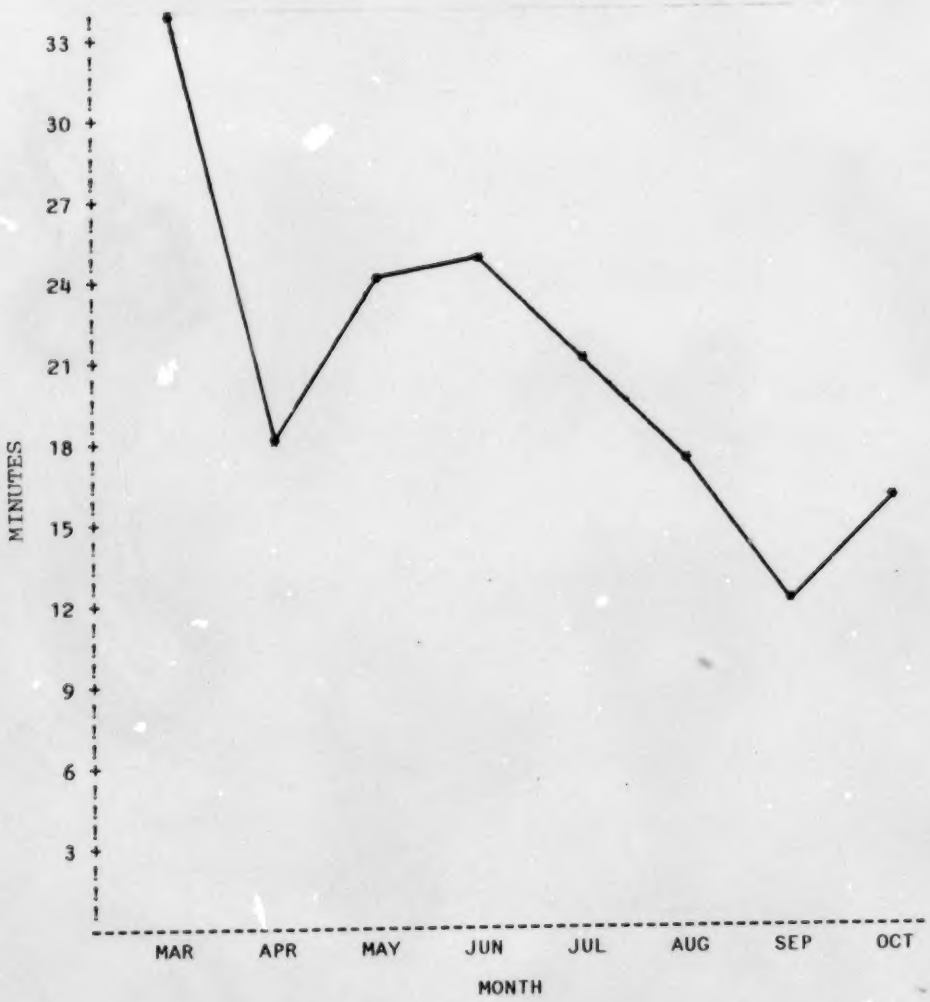

Figure 8. Mean Downtimes by Month for All Observations

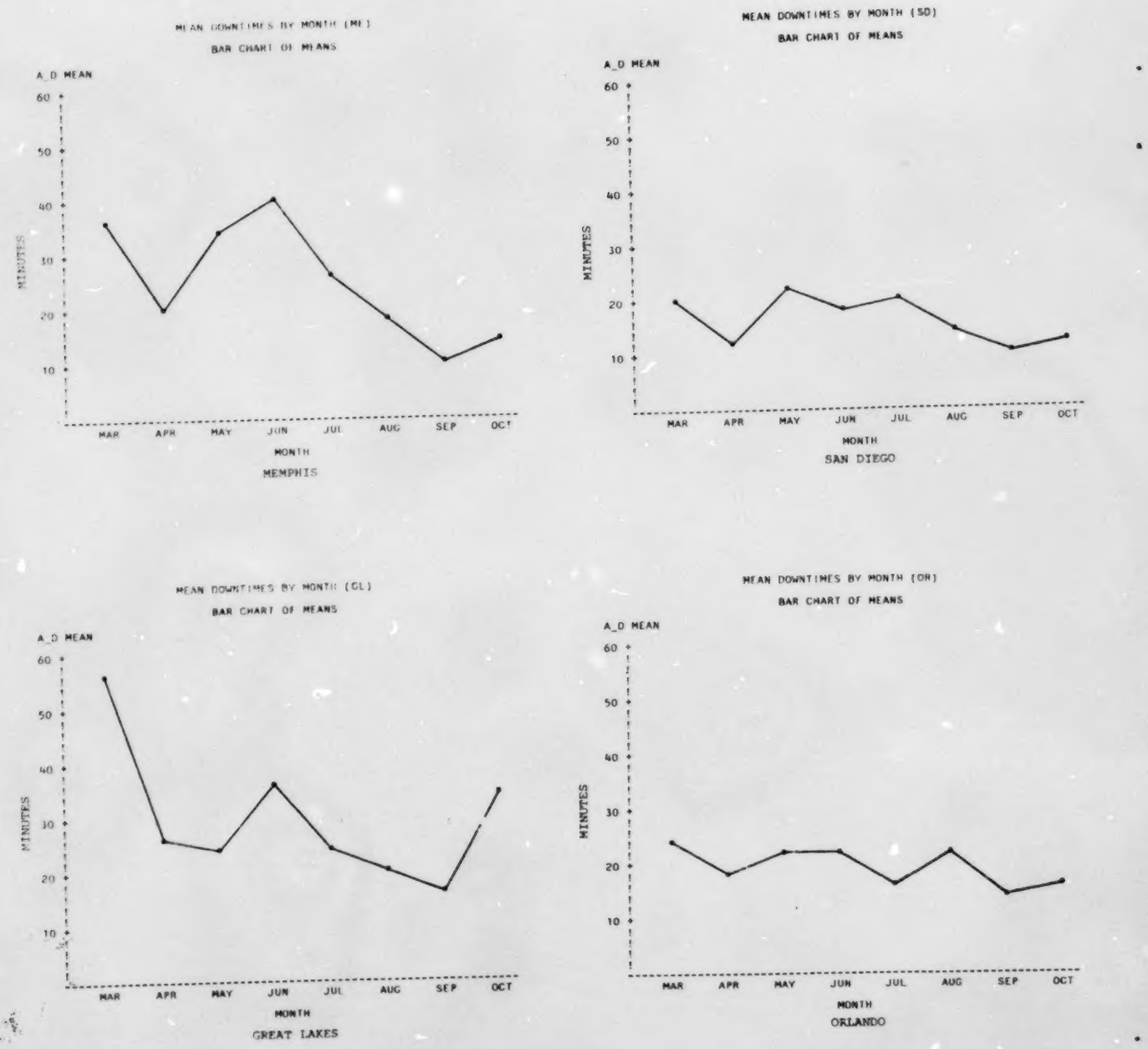

Figure 9. Mean Downtimes by Location

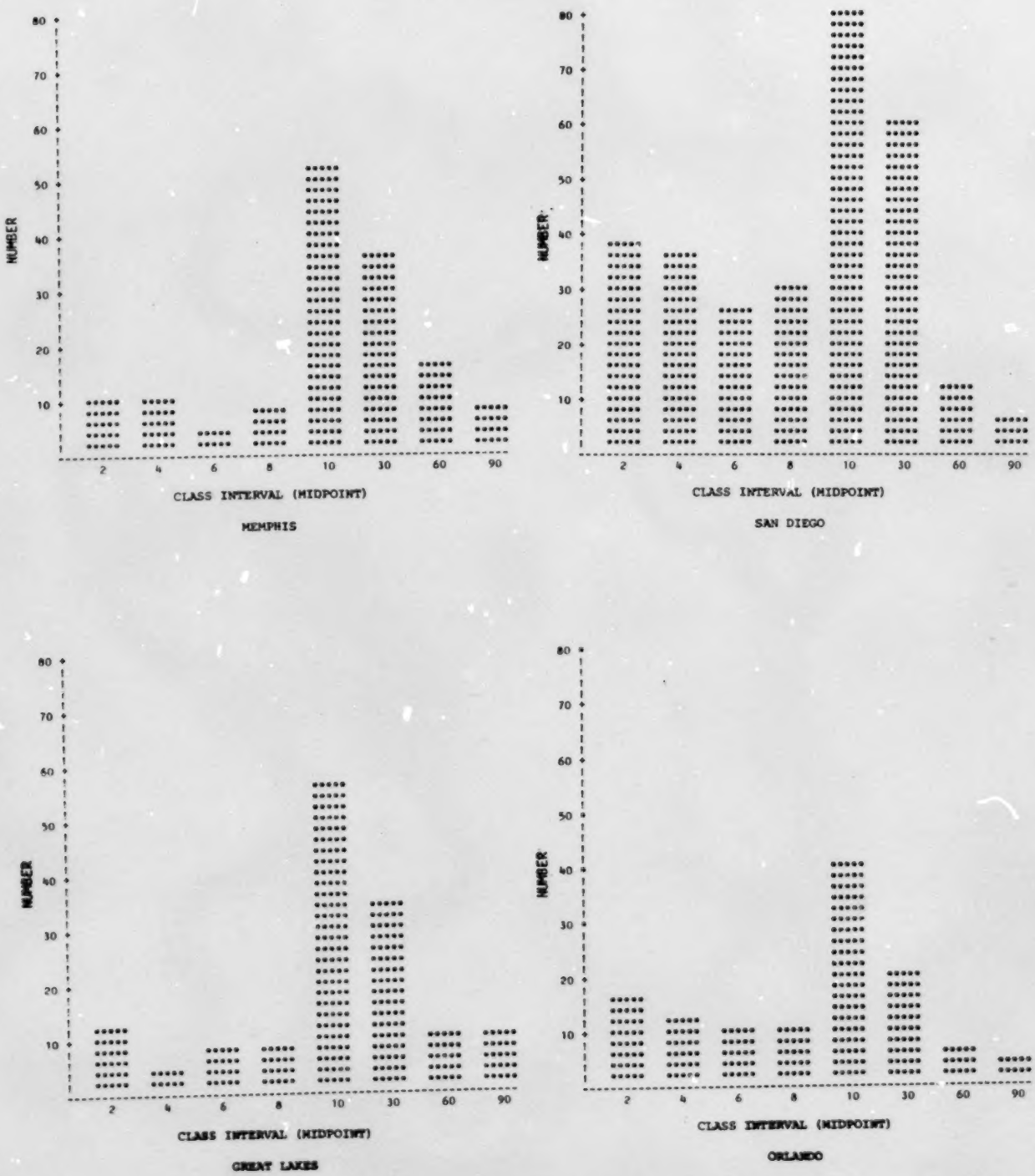

Figure 10. Histogram of Mean Downtimes by Location

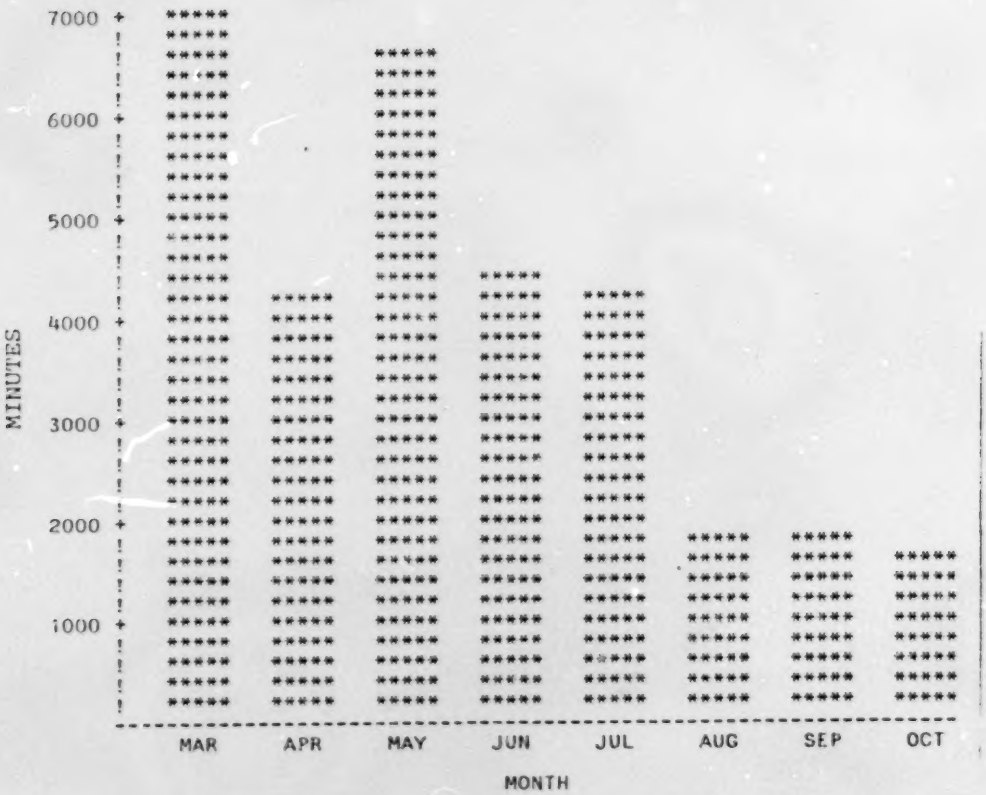

Figure 11. Total Downtimes by Month for All Observations

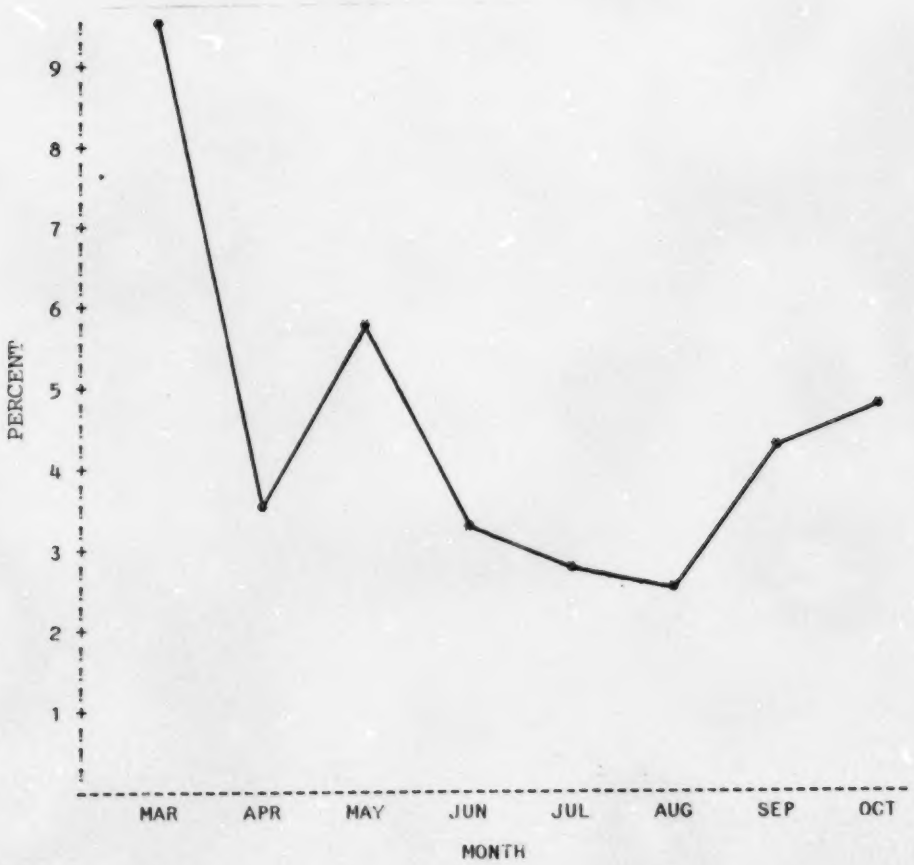

Figure 12. Mean Percentage of Time System Not Available for All Courses

SECTION III

COMPUTER MANAGED INSTRUCTION HARDWARE/SOFTWARE CONFIGURATION

The CMI system hardware configuration is functionally depicted in figure 13. As the figure shows, there are many subsystem elements involved in the processing of one complete CMI transaction. This system characteristic alone could theoretically lead to increased downtimes and response times. However, this does not appear to be the case as evidenced by the statistical data. Findings indicate that excessive downtime and degraded response time are not serious problems for current student loading levels. It is not known, however, how many additional students and courses can be added before unacceptable levels of downtime and response time will be experienced. The elements of this issue which relate to computer hardware and software configuration/capabilities are addressed in this section of the report.

EQUIPMENT HARDWARE CAPABILITIES/LIMITATIONS

Each of the subsystem components shown in figure 13 performs a function within the system and each is subject to failure. Consequently, a failure associated with data entry, data communications, multiplexing, or processing will temporarily cause partial or total system failure. The partial failure case might be limited to an OPSCAN or terminet failure in which case only one of approximately 150 input-output clusters would be affected. This type of failure would normally be corrected in 10 to 15 minutes by replacing the failed unit with a spare. Then the failed unit would be repaired to maintain a backup capability. A total site failure could be caused by an interruption in communications which results in network separation between the site concentrator (Honeywell Level 6) and the central processors (Honeywell series 60 dual processor) at Memphis. If other operable communications circuits could not be used, this failure would remain for the duration of the communications line failure. However, it would only affect operations at the site losing communications. Additionally, the probability of this occurring is reasonably low. The most serious failure would be one in which common elements affecting the dual central processors would fail. This might be due to power failure, fire, flood, or some other similar serious occurrence. For a case of this nature, conceivably the CMI system might be down for days or weeks. Although this type of failure is not very likely, an occurrence would impact a significant portion of total Navy training. It is for a potentiality such as this that a CMI manual backup system should always be available. For networks utilizing a single central processing site, high reliability and reasonable redundancy (both of which have been designed into the existing CMI system) can only decrease the risk of total system failure. Only distributed autonomous transaction processing will assure that total CMI system failure (all subsystems inoperable concurrently) will not occur.

The following discussion will be directed toward specific network subsystem elements in order to provide a more detailed assessment of system capabilities/limitations.

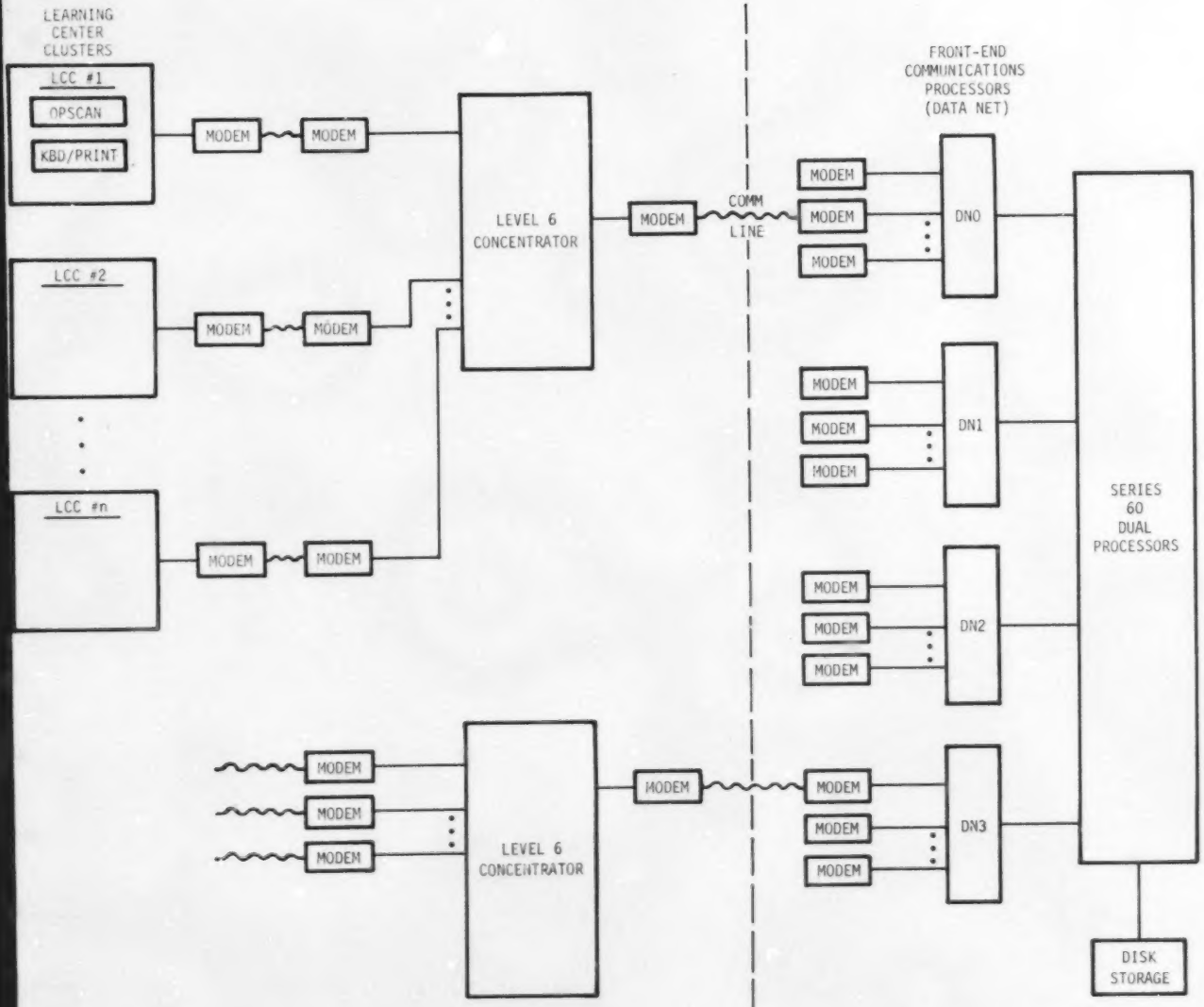

Figure 13. CMI System Hardware Configuration

INPUT-OUTPUT LEARNING CENTER CLUSTERS. The input-output learning center clusters can be used to input student tests, each having up to 50 multiple choice responses, through an OPSCAN-17 optical mark reader or to output learning guides on a Terminet 1200 keyboard/print terminal. This input-output channel can also be used to enter administrative transactions and to receive administrative responses. Input-output control logic for these clusters is contained in the base of the OPSCAN unit. A communications interface to the Honeywell Level 6 concentrator is established via GDC-202-98 modems.

Because the OPSCAN reader and the terminet printer are electro-mechanical, failure rates for these devices are higher than for electronic subsystem elements. These units do have a relatively high failure rate but spares are normally kept on hand, if available, to replace failed units. By using this maintenance strategy, cluster failures at sites with backup units do not objectionably degrade system capability or availability. It does appear, however, that locations without a backup capability could seriously degrade system availability. The control logic and modems have proved to be highly reliable and the communications lines which connect the clusters to the concentrator are similarly reliable. This input-output configuration, although not the best or most reliable by today's standards, provides an adequate system capability. Many improvements are possible for this network node such as hand-held device input, higher speed input, higher speed printer output and keyboard/display testing terminals. However, the present configuration provides satisfactory performance and any proposed improvements would have to be individually assessed on the basis of cost-benefit projections.

HONEYWELL LEVEL 6 CONCENTRATORS. The Honeywell Level 6 concentrators are in essence communications computers which multiplex inputs from the learning center clusters for transmission to the central computer complex in Memphis. Return data in the form of learning guides or administrative responses are also routed to the proper receiving station via this subsystem. Since the data rate on outgoing or incoming communication lines is relatively low in terms of computer capability, response time should not be limited. In addition, the reliability of this equipment has proven to meet or exceed expectations. Although other processing, beyond that required for communications, is accomplished within this computer, only a failure affecting multiplexing or communications would impact student testing. Because all sites do not have subsystem redundancy, it is possible that failure could cause CMI interruptions for extended periods (many hours). Failure data collected for the past 6 months, however, do not show this to be a problem and, in the opinion of experienced personnel, continued high reliability is expected.

FRONT-END COMMUNICATIONS PROCESSORS. The network arrangement between the student input-output clusters and the concentrator is repeated in concept at the Memphis host computer site. For this application a front-end communications processor is utilized to multiplex inputs from many site locations. This processor acts as a temporary buffer and switch directing incoming transactions to buffer locations in main processor memory. This provides temporary transaction data/storage while awaiting central processor service. When service is completed, the transaction response information is routed to the proper output communications channel via the communications processor.

Discussions with system personnel have indicated that the memory limitation on the front-end processors sometimes results in system overload and temporary failure. These failures are not normally catastrophic since a system reboot will return the system to operational status in a period of minutes. It is a problem, however, which should be diagnosed further to determine what corrective measures should be considered.

HONEYWELL SERIES 60 DUAL PROCESSORS AND PERIPHERALS. The equipment at the Memphis central CMI processing center consists of 2 Honeywell series 60 processors, 23 100-MB disk drives, 11 magnetic tape units, 4 front-end communications processors, 2 1200 LPM printers, a card reader, and a card punch. The processors share one mega word of memory and are configured to service multiple users. The multi-tasking, multi-processing operating system combined with the data base management and input-output handling systems combine to provide a powerful and effective computational complex. Although the CMI system uses only a portion of the total resources available (for example, CMI uses only three of the 23 disk drives available), it is the highest priority user and is not affected by other users in terms of response time. A system crash could result from defective non-CMI applications software or front-end processor overload. However, this possibility is not considered serious because most recorded failures in this category have been corrected within reasonable time limits. The peripherals have also proven to be reliable and of sufficient capacity to handle peak loading. An analysis of system capabilities has shown that there are some CMI software characteristics which would limit system expansion. However, it appears that these characteristic limitations could be corrected with some system redesign. This topic is discussed further in the following paragraph.

SOFTWARE CAPABILITIES AND LIMITATIONS

The system resident software in the CMI network consists of operating systems, data base management systems, communications programs, and utility programs. This software, with a few minor exceptions, has proven to be reliable. Some relatively minor modifications have been made to the resident vendor developed software for special applications.

The CMI software which controls transaction processing is considered to be of primary importance. The software consists primarily of an evaluation program, which provides the test evaluation and learning guide generation capability, and a number of administrative transaction processing programs. Although the administrative programs such as registration, class rosters, student progress, and those concerning student flow are necessary for effective school management, normally they are not competing for time with evaluation. They are considered administrative batch operations and are normally scheduled for minimum impact on student testing.

The evaluation program which controls the analysis of, and response to, student tests is the primary response time controlling program. At present, the maximum test transaction throughput rate is approximately two transactions per second (120 per minute or 7,200 per hour). If it were possible to maintain this rate for two six-hour shifts, which is unlikely, 86,400 test transactions could be serviced. This assumes that no administrative

transactions are competing for time and that all answer sheets are properly coded. It also assumes a continuous flow of test input. For the measured case, approximately 35,000 test transactions are serviced each day with the balance of the time being utilized for administrative transactions and error transactions with periods of nonutilization interspersed throughout the day. For the current student loading of approximately 8,500, the existing evaluation capability is adequate. Making changes to the evaluation program to allow for multi-tasking operation within the evaluation program would have the effect of handling many test transactions at a time as opposed to one at a time for the present case.

Upgrading the evaluation program appears to be a relatively simple solution to satisfy a potential need for greatly increasing throughput. However, for a change of this nature, careful study should precede development. This may not be a satisfactory solution unless significant disk and file restructuring accompany the multi-tasking approach. If a single disk access to a course file locks that file out for a following transaction, a wait period of 20 to 50 milliseconds or more might result which could partially negate the expected benefit of multi-tasking. The net result of this situation might be a moderate improvement in throughput and not the significant improvement expected. File reorganization, and new approaches to course file development, if effectively accomplished, together with multi-tasking, should minimize the number of disk accesses and improve the overall response time. By following this approach, high priority file handling could be limited to no more than two disk accesses as compared to the present 5 to 12. This would then be followed by housekeeping transactions which would be accomplished in background mode.

Even if these improvements in the evaluation were accomplished, other hardware and software response time constraints might occur. These constraints might be due to data net overload, student cluster overload, or inadequate buffer storage. It is suggested that a total system network analysis be done to determine the maximum throughput at each node before any single measure is taken to improve system performance. One obvious approach to system expansion, if required, would be to provide a distributed processing capability at each site. Although this approach has certain detrimental effects which would offset some of the benefits to be gained, it appears to be a reasonable expansion option. This issue is discussed in the following paragraph.

DISTRIBUTED PROCESSING CONSIDERATIONS

The phrase "distributed processing" is often suggested as a solution to many of today's data processing problems. Whether the problem is response time, insufficient storage capacity, or data base management inadequacy, there is a tendency to favor a corrective measure in the form of distributed processing. This assessment of distributed processing stresses the need for cautious evolutionary development when considering this alternative for CMI system expansion.

It appears inevitable that distributed processing will play a significant role in the future and could provide the means for greatly increasing current system capacity. However, it should not be considered a potential

cure all. The primary question which should be addressed when assessing this option is, how many and which processing functions can be efficiently distributed. There are also questions concerning loose or tight coupling within the network, the necessity for distributed data base management, communications protocol, privacy/security/integrity, and network management/control. Dispersing many CMI processing, storage, and reporting functions without maintaining strong and effective centralized policy development and management control could bring about a degradation in CMI system performance instead of the desired improvement.

The distributed approach has many advantages. It would not be necessary to communicate student test response data hundreds or thousands of miles for response analysis and learning guide generation as is now the case. Test transaction processing is well within the capability of medium scale computers which could be located at remote sites. A remote computer of this type could also provide the processing functions associated with class roster generation, predicted completion time (PCT) resource allocation/scheduling, and site level administrative support. However, it might not be in the best interest of the Naval Education and Training Command to distribute such functions as student registration, student record keeping, student tracking, and training pipeline management. These examples are not offered as recommendations. They only demonstrate the extent of the analysis required before making hard decisions relating to CMI configuration changes. They also demonstrate the necessity for an in-depth analysis of CMI long-range requirements before selecting a course of action for system redesign.

SECTION IV

NON-CMI USERS

The Honeywell 6000 computer system, located at Naval Air Technical Training Center (NATTC), Millington, is used for more than CMI support (see figures 14 and 15). This system supports numerous other functions including naval technical training, recruit training, and miscellaneous activities.

The largest single user (where use is measured by processing time) is the Military Personnel Information System (MILPERSIS). Information is passed to MILPERSIS throughout the day to update various data concerning students within CNTECHTRA. Intense MILPERSIS use of the Honeywell 6000 system is reserved for the 1800-2300 Central Standard Time period when CMI use is very low.

The second and third largest users of processing time are CMI and the maintenance of the MIISA General Computer Operating System (GCOS). Together, these three large users--MILPERSIS, CMI, and MIISA operating systems maintenance--account for approximately 85 percent of the Honeywell 6000 processing time. The remaining 15 percent is used for numerous functions, including primarily:

- Standard Transfer Directive Module (STDM) for ordering the transfer of students
- NATTC, Millington, civilian and military payrolls, and civilian personnel support
- NATTC, Millington, logistical functions; e.g., Navy Stock Fund and Resource Management System
- U.S. Army Corps of Engineers support
- Individual Flight Activity Report Subsystem (IFARS) for managing flight personnel. The Honeywell 6000 relays IFARS data from Memphis to Pensacola for central processing.
- Surface Warfare Officer School support
- Availability Reporting and Tracking Module (ARTM) and Recruit Accession Module (RAM) to aid in personnel management within the Recruit and Student Training Commands. Although this support is provided primarily on Level 6 systems, the Honeywell 6000 does provide some central processing support.
- Naval Air Maintenance Training Group and Air Maintenance Detachment support
- Computer Driven Training System which provides CAI-like instruction in computer use.

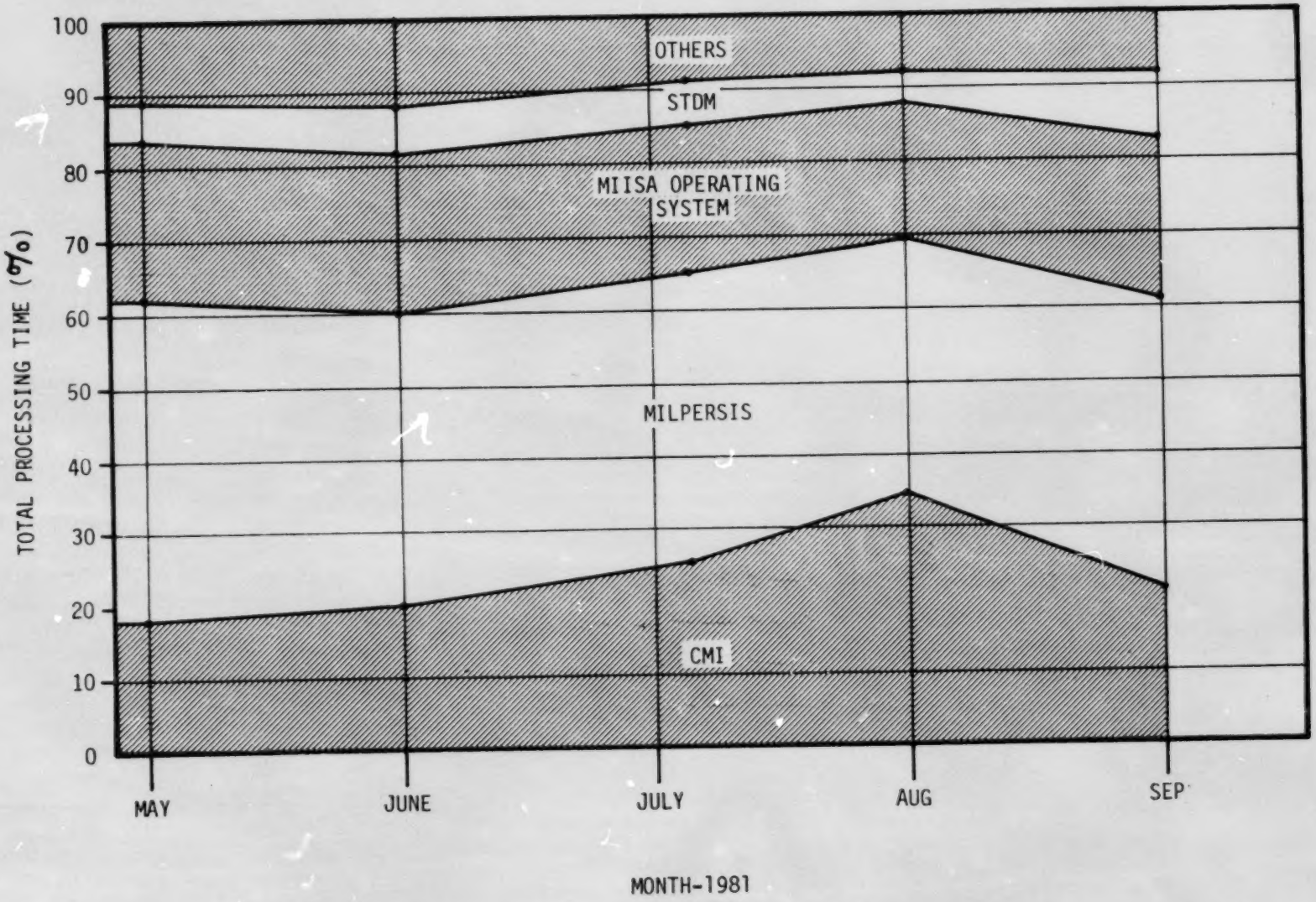

Figure 14. Distribution of Honeywell 6000 Processing Time (%) Among Users

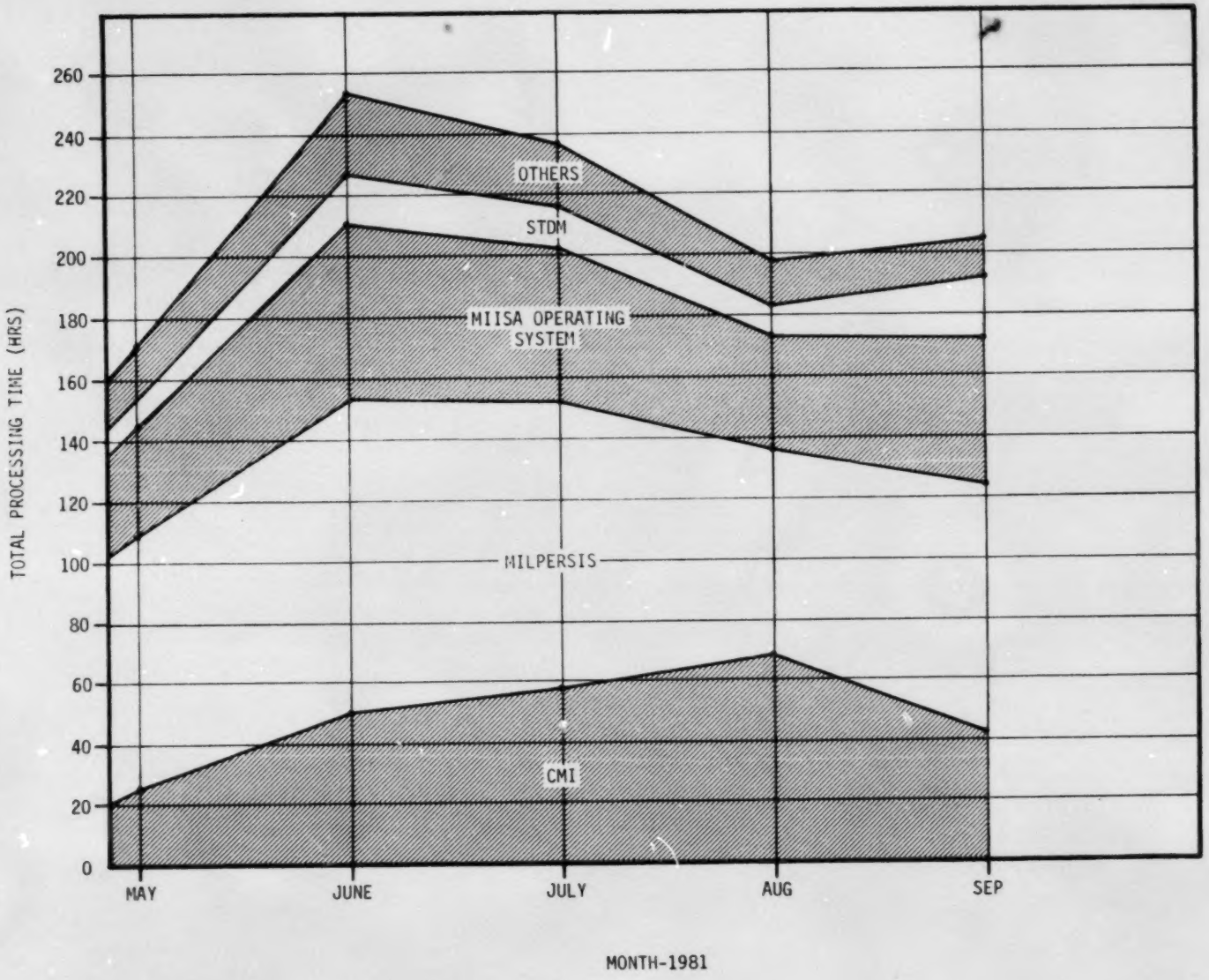

Figure 15. Distribution of Honeywell 6000 Processing Time (Hrs) Among Users

Currently, there is no statistical basis for relating degraded CMI performance to non-CMI user applications. Performance indicators reviewed show typical CMI response times of 3 to 5 seconds and overall system availability exceeding 95 percent. In addition, there is no indication that non-CMI users cause more than a proportionate number of failures of those recorded. It is obvious that non-CMI use will increase the probability of total system failure, but it can not be determined at the present time if this increased risk of failure would warrant a reduction in service to non-CMI users. By allowing multiple users, system utilization is increased and the return on computer investment is positively affected. Although there are a number of ways to improve the operational availability of the CMI system, as discussed in section III of this report, it appears doubtful that limiting non-CMI use beyond current levels would have any significant impact.

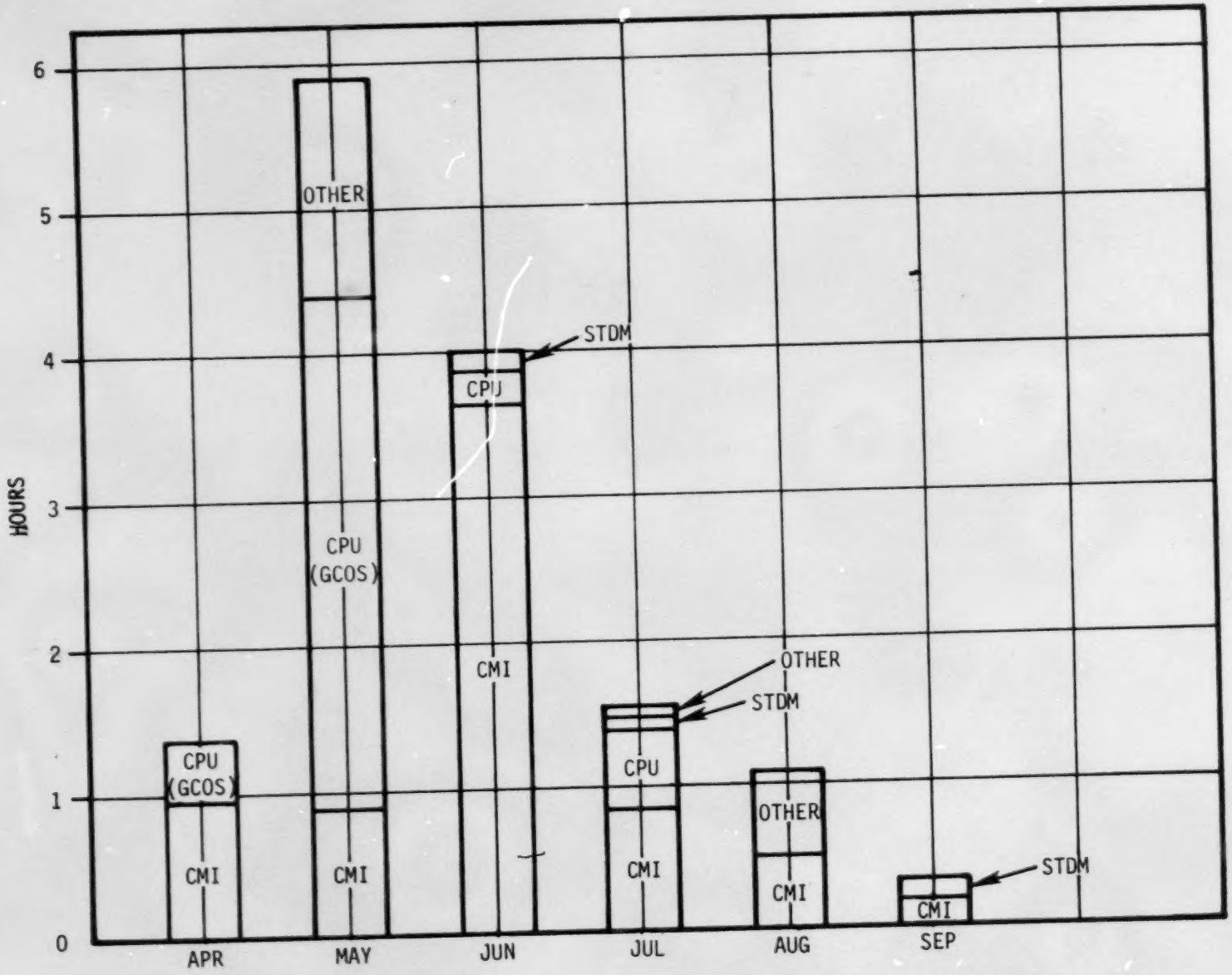

Figure 16. Honeywell System Downtimes (Beginning at 0600 (CST) Weekdays and Running for 20 Hours)

SECTION V

RELATIONSHIP BETWEEN CMI DOWNTIME AND STUDENT TRAINING TIME

IMPACT OF COMPUTER DOWNTIME

The most obvious and potential impact of CMI downtime on the cost of training arises from extending the time required for students to complete training. An objective determination of how CMI downtime affects training time requires the collection of data on student activity during downtime and the use of empirical measures of training time as a function of CMI availability. Such data were not collected during past CMI downtimes and during the period covered by this study availability was so high that there was an insufficient number of adverse effects from which to deduce a functional relationship between downtime and training time.

At least two important factors contribute to the relationship between training time and CMI downtime. The first arises from the role of CMI in the instructional process. The Navy CMI system itself is not designed to provide instruction during the time the student interacts with the computer. Apart from the incidental learning which takes place during tests, the majority of instruction occurs while the student is in the carrel and not interacting with the computer. The computer provides periodic performance evaluations and directs the student in future study assignments by issuing learning guides. Consequently, when the computer is down those students who are not ready for a performance evaluation will not be directly affected. If the downtime interval is very short (as most have been in the last four months) and the frequency of student interaction is low, then very few students would even be aware that the CMI system was down and there would be no impact on those students. For those students who were affected, the average waiting time for the computer would be only a fraction of the computer downtime, assuming students demand service at a constant and uniform rate during the shift.

The second factor which impacts on the relationship between training time and CMI downtime is how the student is managed in the classroom once the student demands service and finds the computer down. Arguments are frequently advanced that the amount of lost training time for any student can be measured from the time the student demands service and finds it unavailable to the point he/she obtains the requested service. This argument must be predicated on the assumption that learning stops when required CMI service is not available. Since the computer plays its role in the management of instruction, and not the instruction itself, such an assumption is untenable.

One alternative for obtaining data from which to derive the relationship between training time and computer downtime would be to devise an experiment in which data on student queues, training time, and effectiveness would be compiled and analyzed following controlled CMI shutdowns. Such an experiment was considered not to be feasible with the operational CMI system.

An alternative to the experimental approach is to perform a logical analysis of the problem using qualitative data drawn from previous research dealing with CMI systems and discussions with school management as to how current CMI shutdowns are handled. The following discussion is based upon an analysis of those factors which determine the training time required by students, an analysis of how the computer/CMI system interacts with those factors which determine training time, and an assessment of the management of students at the schools when the CMI system is down.

FACTORS INFLUENCING STUDENT TRAINING TIME

A review of training literature shows that "student training time" has many components. Carroll (1963) identifies five factors which interact to determine the total student training time. These include: (1) time allowed for learning, (2) time the learner is willing to spend, (3) time required because of the student's ability, (4) ability to understand instruction, and (5) quality of instruction. Bloom (1976) has demonstrated that through individualizing instruction, considering each student's unique status with respect to the above five factors, certain conditions of learning can be established which facilitate the student in learning. The importance of these conditions for the present problem is evident in the statement, "... what any person in the world can learn almost all persons can learn if provided with appropriate prior and current conditions of learning" (Bloom, 1976, p. 7). When these conditions of learning are optimum, we can get almost anyone to learn almost anything. There are six conditions:

1. Prerequisites (PRQ). These are the knowledge and attitudes that students bring to the learning situation based on previous experience. ASVAB scores and reading and computational scores are often used to assess this condition. Attitudes are reflected in measures of motivation and perseverance. The best adaptive instruction accommodates student variation among the prerequisites.

2. Cues (CUE). This condition involves the ways the instructor informs students what they are to do, and includes learning objectives, verbal explanations, demonstrations, and models.

3. Participation (PAR). In order to learn, the student must overtly or covertly do something. Both instructors and the instructional materials must keep the student's mind intently engaged with the subject matter. A very high relationship exists between such mind engagement and amount learned. Such "mind engagement" time is not necessarily related to the amount of time a student spends in the carrel. PAR is the study time that remains after subtracting wasted time from the time a student spends in a learning center or laboratory.

4. Reinforcement (RNF). A reinforcer is part of the reward or motivational system that strengthens the behavior that precedes its administration. The definition is circular in that if the behavior is not strengthened, whatever was administered was not a reinforcer. In the science of instruction, here is where the "art of teaching" comes in. There can be no formula for the use of reinforcers. It takes a wise and sensitive instructor to know when to use external reinforcers such as recognition or

privilege and internal reinforcers such as leaving the student alone when the instructional materials are obviously strengthening PAR.

5. Feedback (FBK). This is the information that informs students of the degree to which their practice is discrepant from that which they are supposed to be practicing. Sometimes FBK and RNF are the same; other times FBK is neutral. Tests, critiques, and oral examinations are used for this function in an individualized instructional system.

6. Correctives (COR). After the FBK shows a discrepancy between the required and the demonstrated response, the corrective prescribes some sort of learner activity that will eliminate the discrepancy.

Wherever there is efficient and effective instruction, individualized or lock-step, these six conditions of learning are present.

A LOGICAL ANALYSIS OF QUEUES AND INTERRUPTIONS IN THE NAVY CMI SYSTEM

The Navy CMI system is designed to assist primarily in two of the above six conditions, namely feedback and corrective functions. The CMI program is tailored to assist the learning center instructor (LCI) in providing alternative forms of tests, retakes of examinations, and prescriptions for corrective actions for student weaknesses. Information contained in the CMI system Student Progress Reports also serves the prerequisite and participation functions. If a student progresses through one or two instructional modules every day, takes 30 minutes to take a test and score it at the OPSCAN terminal, and demonstrates mastery on about the second attempt, a conservative estimate of the proportion of his or her total learning center time spent in test taking would average approximately one hour per day. Even during this period, it is estimated that the student would interact with the computer for less than five minutes of the time. When the CMI system is down, learning need not stop, although the sequence in which the student undertakes the learning experience is usually modified.

The flow diagram in figure 17 is based on how a CMI learning center activity might operate when the computer is down. There are five key points in the model where student queues might be expected to develop following an extended period of computer downtime. They are awaiting:

1. the first lesson or module assignment in the course,
2. instructor help or approval to attempt a formative or module examination,
3. examination scoring and study assignment at the OPSCAN terminal,
4. instructor diagnosis, counsel, and prescription following failure to demonstrate mastery on a test, and
5. assignment or materials for the next lesson.

These points are noted as QUEUE1 through QUEUE5, respectively, in the flow diagram. As the diagram shows, four of these possible delays are directly related to the LCI's availability of time.

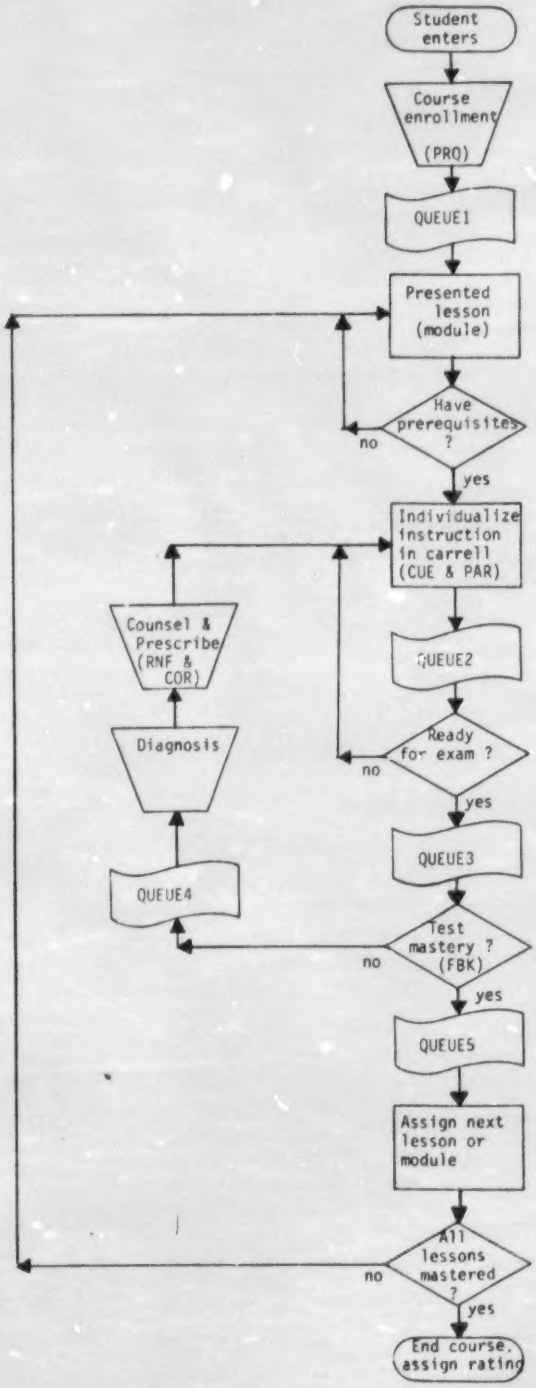

Figure 17. Flow of CMI Student Activity

Following a shift to the manual mode because of a computer failure, the LCI must become occupied with keeping the students productive. This involves keeping them actively pursuing course goals and manually entering updated student information into the records system. Perfectly designed instructional materials would support the important conditions of learning so that the instructor would be free to carry the computer's share of the management. Since the instructional materials are seldom so designed, it is reasoned that the instructor would eventually become involved in all phases of the instruction and such manual management activity will begin competing with the students' needs for cues, feedback, reinforcement, and correctives. Many factors would determine how long the computer must be down before this overload would become a serious problem. It is estimated that on the average it would not become a serious problem for downtimes under 1 hour.

MANAGEMENT OF STUDENTS DURING COMPUTER DOWNTIME

Figure 17 illustrates how instructors might intervene at each QUEUE position should the computer system fail. Presently, instructors do not usually intervene (at QUEUE2) to determine, by oral examination, that the student is ready for the test and has a high probability of being successful --but if they were required to go into a manual mode this intervention would be necessary. Presently, the QUEUE3 requires a short wait for scoring and test results--but in a manual mode, this wait would certainly be longer. Instructors do not necessarily override the study assignment accompanying the printout of test results in order to give a personal diagnosis of learning difficulties--but they can, and in a manual mode they would provide the personal diagnosis.

A hypothetical example of how a competent LCI who knows his or her students should manage computer downtime would be as follows:

Students who are known to have conceptual difficulties with the prerequisite learning modules and are running far behind their predicted completion time (PCT) are requested to spend additional time studying in their present module. Such study could be in an additional method of presentation, such as the summary, narrative, or programmed instruction mentioned in NAVEDTRA 110A. It could be in the form of an elaboration of the module goals by film, filmstrip, trip to the lab, or peer instruction by an advanced student. The goal of such activity would be for the student to demonstrate mastery of the present module on the first attempt. Such "overlearning" is not necessarily inefficient for this student; it may be the learning-how-to-learn, or the confidence-builder, that will cause him or her to "takeoff" after the CMI system comes back on line.

For students who are ahead of their PCT and who generally demonstrate mastery of modules on the first test, the instructor would present subsequent modules. The time required for testing seems to slow these students' progress. They study in the learning center or lab for the knowledge, not just to pass tests. Such students can go back and successfully take several module tests without any debilitating effects long after the computer comes back on line.

For the majority of students between these two extremes, a period of computer downtime will require an LCI who has the ability to differentiate

among students and manually make assignments. In order to ensure that the students make effective and efficient use of their time, the assignments must be based on the students' progress with respect to their PCT, their motivation, and their self-reliance. Instructors must be able to effectively utilize audio-visual aids and other materials which are available to ensure student progress. The management of the student during computer downtime provides an opportunity for LCIs to demonstrate how essential they are in facilitating the conditions of learning. It is not easy, and periods of downtime are not without stress, but instructors should be selected who can handle problems which arise during periods when the computer temporarily fails.

EVIDENCE OF THE IMPACT OF COMPUTER DOWNTIME ON TRAINING TIME

There is little empirical data demonstrating the effect of computer downtime on training. The evidence which does exist seems to suggest that computer downtime need not halt student progress.

Several studies (Judd, McCombs, and Dobrovolny (1979); Diamond (1969); Ammentorp, Morris, and Miller (1973)) have demonstrated, in general, that even though the CMI/CAI systems they were studying had interruptions, students could still maintain acceptable progress if their time were adequately managed. Difficulties which had to be overcome included the need to provide adequate student feedback and student time management. In general, the manual management methods were less efficient than the computer.

Two Navy CMI sites (Memphis and Orlando) were visited to obtain data on the effect of computer downtime on training. The following questions were posed to school staff personnel who have had experience with the CMI system:

1. How often does the computer system go down?
2. About how long does the computer usually stay down?
3. What do learning center people do when the computer is down?
4. Do you have a manual or back-up system?
5. How long are learning center queues per downtime?
6. How long must the system be down to affect student time to mastery?

Individuals who responded to the above questions were generally cognizant of problems which existed before March 1981--the last time there were any appreciable downtime problems. There are several generalizations to be drawn from responses to these six questions. First, there have been very few problems since March 1981 in terms of response times or interruptions. When there were interruptions, they have not lasted for more than a few minutes. Second, most learning centers do not have a paper and pencil back-up system for testing, so during downtime students do additional study. If the students are taking a test, they just review their work a little longer before submitting it to the OPSCAN. If the downtime is long, the LCI assigns the students the next instructional module in their learning sequence. Finally, queues following the return of the computer are usually very short, although there were examples of nearly 2-hour queues which occurred over a year ago.

The question of how long the system must be down before there would be an adverse effect on training time produced responses which varied from 15 minutes to 1 hour. Much of the variation in these estimates could be attributed to how well the school was staffed, prepared, or had available back-up procedures.

The cost of computer downtime can be computed under two alternative assumptions. The first assumption (Case I) would represent an upper limit to the cost of computer downtime, except perhaps for extremely long downtimes of several days during which the entire training program might need to be restructured. Case I assumes that for each minute a student spends waiting for the computer that training time is extended on a one for one basis. The formula for computing lost training time for Case I is as follows:

$$L = (1/2)(C)(S)$$

where: L = Lost Training Hours
C = Hours Computer was down
S = Students demanding service per hour

The second assumption (Case II) is based on assumptions about the effect of computer downtime on training time which seem more realistic as determined from data collected for this study. First it was assumed for downtimes of 30 minutes or less that there would be no measurable increase in training time. For downtimes with a duration between 30 minutes and 60 minutes, training time would be extended for one-half the student waiting time. And, finally, for downtimes which exceed 1 hour there would be an extension of training time equal to the amount of time all students spend waiting for the computer. The equations used for Case II are as follow:

$L = 0$: If $D \leq 1/2$ Hour
$L = (1/2)(1/2)(C)(S)$: If $1/2$ Hour $< D \leq 1$ Hour
$L = (1/2)(C)(S)$: If $D > 1$ Hour

where: D = Duration of Interruption.

SECTION VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

The present performance of the CMI system, as deduced from data collected during March to October 1981 showed that response times were satisfactory, averaging less than three seconds per transaction, and the frequency and duration of interruptions were relatively low. For most days, the system was available 95 percent or more of the time during which the schools were in operation. While there were rather severe problems in response time and interruptions prior to March, improvements in system software and operating procedures have significantly reduced these problems. The system does not have the most efficient design in terms of disk access and other system software and potential exists for upgrading system capacity by implementing some design change in these areas.

The largest single use of the present CPU is MILPERSIS followed by CMI and then the maintenance of the MIISA operating system. Together these three uses account for 85 percent of the total processing time which is used. However, all uses together do not fully utilize the available capacity although there are periods during the day in which the system is nearly fully utilized. Computer Managed Instruction is effectively given precedence over all other users through allocation of CPU time. Consequently, at the present level of utilization the non-CMI users do not appear to significantly impact CMI processing. Even during those periods in which the capacity is being fully utilized, CMI is allocated all the processing time required. There is some minor contention for disk access between MILPERSIS and CMI and under worst case conditions CMI performance degradation is estimated at 5 to 10 percent. It is expected, however, that continued expansion of CMI will ultimately force delays in the processing of non-CMI transactions. As previously indicated, the level of loading at which delays will become significant can only be determined by conjecture using currently available data. Development and maintenance work on both the CMI and non-CMI software and hardware is usually scheduled during off duty hours. Such scheduling reduces the impact of development work on the effective operation of the CMI system.

CONCLUSIONS

The essential and most relevant management problem is to determine alternatives which are both technically and economically efficient to enable the system to maintain performance and to provide for future growth. Before any meaningful economic analysis can be performed, it will be necessary to determine at what point increased CMI loading will cause problems. It will then be necessary to determine the source of the problems, and then to evaluate alternatives for overcoming them.

Factors which would adversely impact the operation of the current CMI system could only be postulated and cannot be deduced or observed from any degradation in performance of the CMI system as it is presently operating.

File access procedures, hardware limitations, system design, non-CMI processing requirements, fluctuations in CMI processing requirements, and many other factors interact in such dynamic fashion that even those intimately familiar with the existing system cannot conclude at what level of increased operation significant degradation in response time would occur. While it is reasonable to assume that the system will become overloaded at some increased level of operation, it is not readily apparent what hardware or software components or management problems will prove to be the "weak" link.

Two methods can be used to determine what improvements will be required in order to maintain system performance as more students are placed under the CMI system. First, a comprehensive simulation model would provide one means of determining the system limitations and enable queries of the "what if" type relating to system upgrading. Simulation could also be used to determine if, and to what extent, system performance will be degraded by demands for service from non-CMI users such as MILPERSIS. Various alternative improvements could be modeled and costed and the most cost-effective alternative identified. A generic CMI simulation model is currently being developed which may be used to support studies of this type for system expansion.

Second, the student load on the present system could be carefully and gradually increased until significant performance degradation becomes apparent. There is at present no reliable way, either objectively or subjectively, to determine at what level of student loading such performance degradation will occur. However, as performance degradation occurs, as it inevitably will, corrective action can be taken to maintain system performance. Such corrective actions must be technically feasible and should be economically efficient. There are indeed certain risks associated with the continued expansion of the present CMI system, but these risks appear minimal. The most serious problem would be complete and prolonged system failure resulting from overloading which appears to have a low probability of occurring. The more likely impact of overloading is a steady increase in response time. A reasonable increase over the existing response time of two to three seconds could be tolerated without having a significant impact on training time since system specifications call for a response time of 30 seconds or less. This would indicate that current response time could be increased without system specifications being exceeded.

It is inevitable that at some point computer downtime will affect training time. However, the present study was concerned with both duration of downtime as well as the frequency of interruptions and to what extent these have impacted on training time. Available data does not suggest a direct one to one relationship between computer downtime and length of student time in training. In fact, the data available suggests that short (30 minutes or less) and relatively infrequent downtimes have a minimal impact on student learning for a CMI system. Student time to mastery is related to time spent in fulfilling certain specified conditions of learning. Most of the student's studying and learning experiences in fulfilling those conditions do not involve the computer. Computer downtime could only affect the learning rate of those students who demand service and the number of students demanding service will depend on the length of downtime and frequency of student interaction with the computer.

Most learning centers do not have a complete manual back-up system. However, where such systems exist, they appear to be very effective in minimizing negative effects of computer downtime. Properly designed back-up systems could be developed which would be effective in managing prolonged downtime. The high availability of the CMI systems makes it questionable whether the development and maintenance of full-scale back-up systems would be cost effective. Most of the school staff consulted during this study were of the opinion that there was no measurable impact on training time from the relatively minor interruptions which have occurred during the latter part of the time period of this study. However, staff estimates of how long the computer must be down before there would be a significant extension of training time varied from 15 minutes to 1 hour. From the above analysis it is estimated that the computer would, in most cases, need to be down for an hour or more before training time would be extended significantly. Between March and October 1981 there were relatively few instances where the CMI service to a course was down for an hour or more during the entire shift. Approximatley 95 percent of the interruptions lasted 30 minutes or less.

It is reasonable to assume that a degree of distributed processing should be considered for any major expansion of the current CMI system. Possible advantages of distributed processing include elimination of the need for communication lines to process student transactions, the improvement of local command control and service, and the provision of redundancy where possible. Disadvantages include the potential loss of central control, possible scale diseconomies, and increased difficulty in maintaining software and hardware standardization. The cost effectiveness of distributed processing will depend, in part, on the costs of upgrading the existing system as well as development and implementation costs of a distributed system. More data needs to be collected to determine the requirements and costs of upgrading the present system. Simulation would provide a basis for obtaining these data. At this time, there is not an acute need for a major redesign of the present system. Subject to a rapid and unexpected increase in courses placed in the CMI system, time is available to make a complete assessment of system need and to formulate a conceptual system design prior to any new development and implementation. Additionally, prototype implementation and evaluation are recommended before considering wide-scale application. A site phasing implementation plan should be developed which would assure training continuity during distributed system integration.

As stated previously, the existing system is a good one and it can be expanded. Every possible step should be taken to assure that a replacement system will perform more efficiently. It should also be noted that a replacement system will form the basis for Navy computer based instructional management during the next decade. If the concept formulation phase of this development does not include life cycle cost benefit assessment and if state-of-the-art network/communications/data base architectures are not considered, there is a high probability of serious consequences for Navy training. The training community may be forced to live with a deficient system.

Distributed processing is not a fixed approach to data processing but can encompass a wide range of software and hardware configurations. Distributed processing also requires decisions about which functions can most

effectively or efficiently be processed remotely at the school rather than at a centrally located facility. Consequently, there can be a large number of alternative systems defined as distributed processing which will be capable of providing the required future CMI services. A number of the technically feasible alternatives should be evaluated in order that the most cost-effective system can be identified for implementation.

A final and obvious conclusion is that if the CMI processing requirements continue to increase, the CMI system will eventually be overloaded and require upgrading. At least two important areas must be addressed to determine the most cost-effective way to upgrade the system. First, the maximum efficient capability of the present system is unknown. Presently, there is no reliable way to identify the potential difficulties which will be encountered with increased processing requirements; therefore, there is no reliable way to determine the marginal cost of upgrading the present system. Simulation or future experience gained from increasing the load on the present system will eventually provide answers to this problem. Second, at what point the processing requirements will exceed the capability of the present system depends on the rate and processing requirements of new courses brought under CMI. The processing requirements may not increase as rapidly for group-paced courses requiring only testing support as they would for self-paced courses.

RECOMMENDATIONS

1. Develop a comprehensive simulation model which will provide a capability for determining "bottlenecks" in the present system and for evaluating alternative CMI expansion strategies. Such a model would provide insight into the efficiency and effectiveness of alternative expansion strategies.

2. Develop, implement, and evaluate a prototype distributed processing system. Such a system should be ready for operational implementation when and if it becomes noneconomical to further expand the present system.

3. Using data from a planned CMI course implementation schedule, the simulation model, results from the prototype distributing system, and the technical capabilities of microcomputer technology, develop a long-range plan for system expansion. Options should include expanding the present CMI system, implementing distributed processing, and viable options which utilize both approaches.

4. Develop a workable strategy for managing the students during computer downtime with emphasis on short interval interruptions.

5. Because of high system reliability, reevaluate the cost-effectiveness of existing requirements for developing and maintaining comprehensive manual back-up systems to manage students during the longer downtimes.

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A P P E N D I X

CMI PERFORMANCE STATISTICS

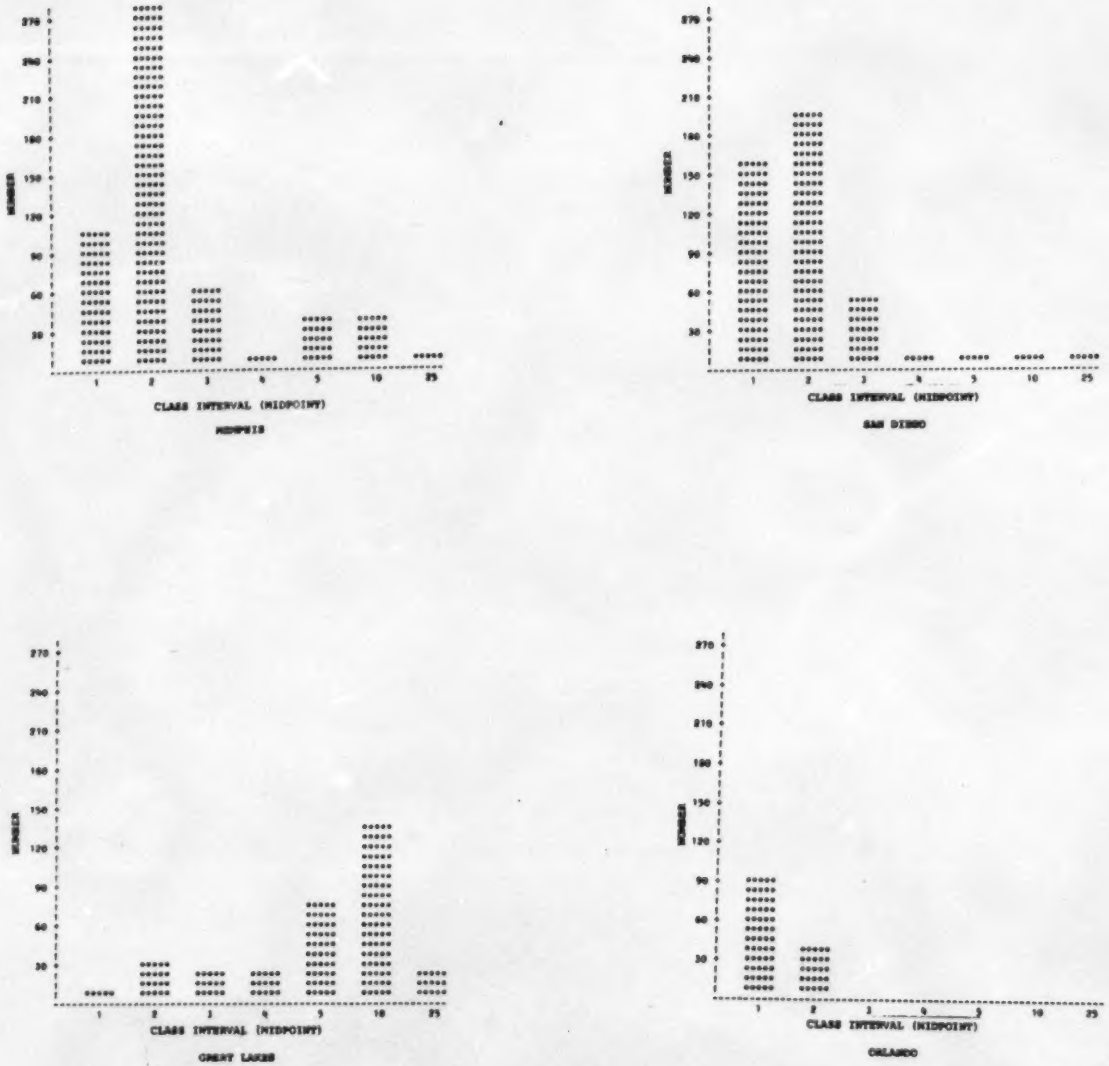


Figure A-1. Histogram of Mean Response Times by Location

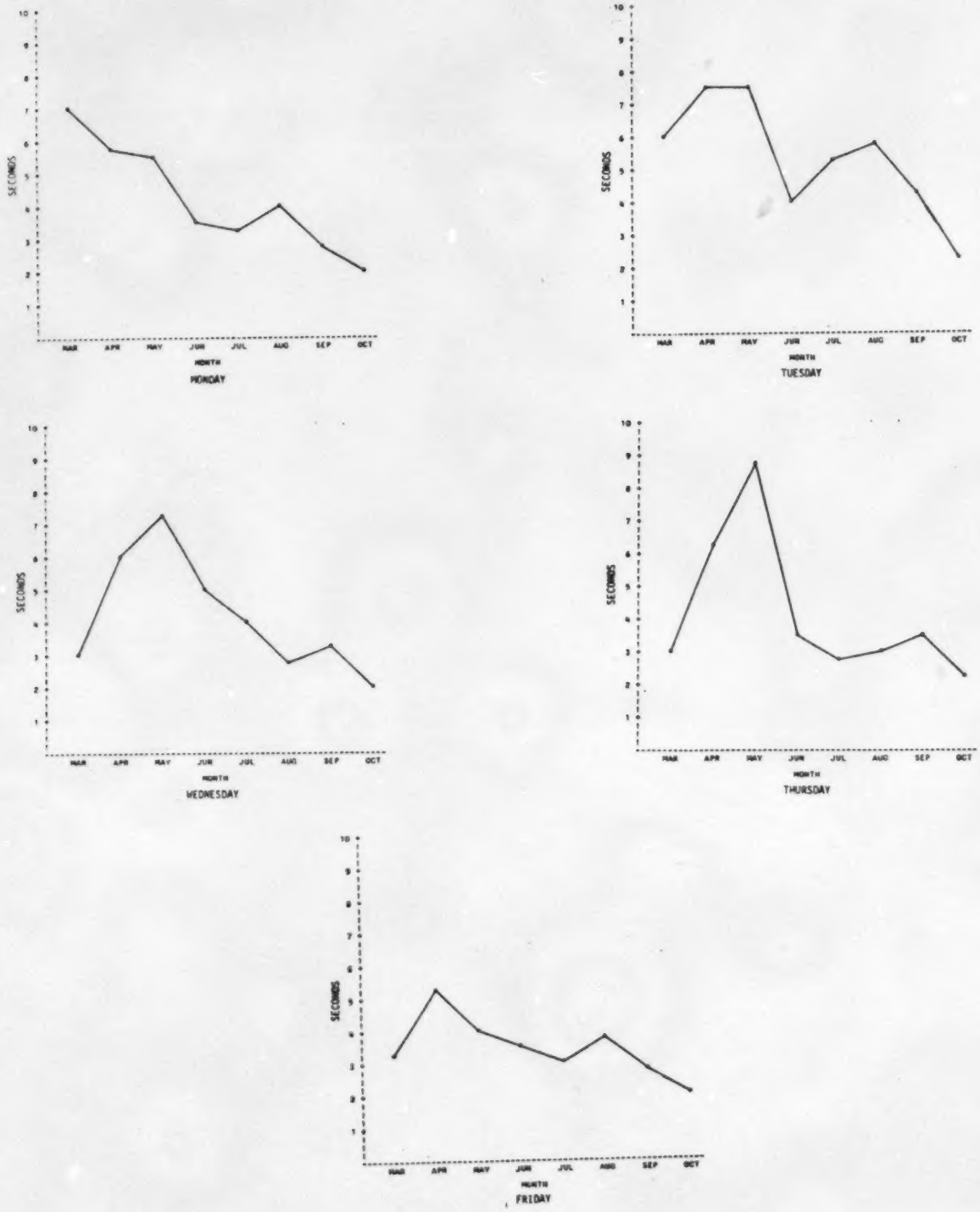
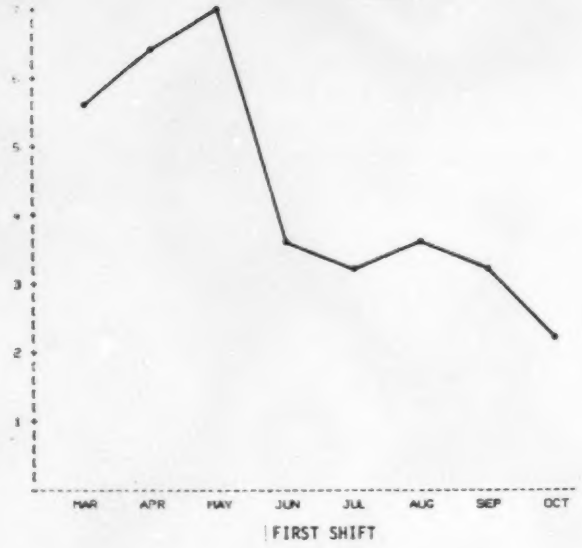


Figure A-2. Mean CMI Response Time by Day of Week



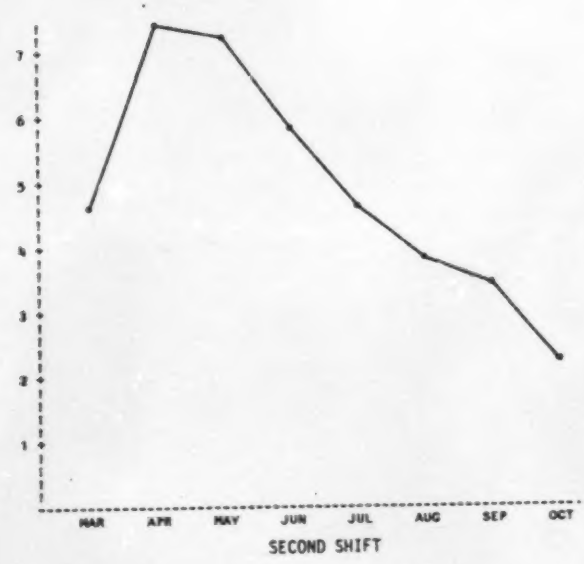


Figure A-3. Mean CMI Response Time by Shift

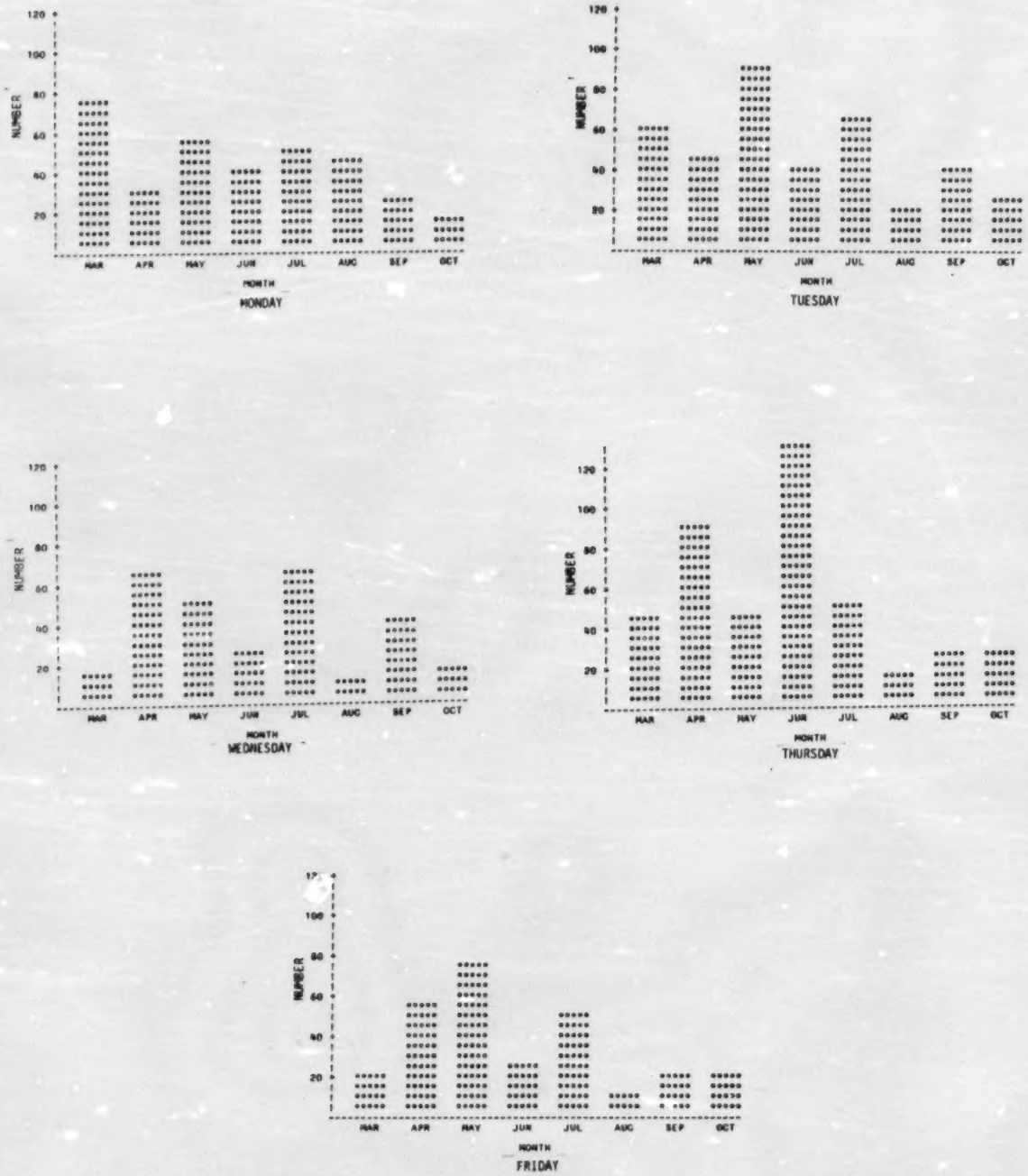


Figure A-4. Total Interruptions by Day of Week

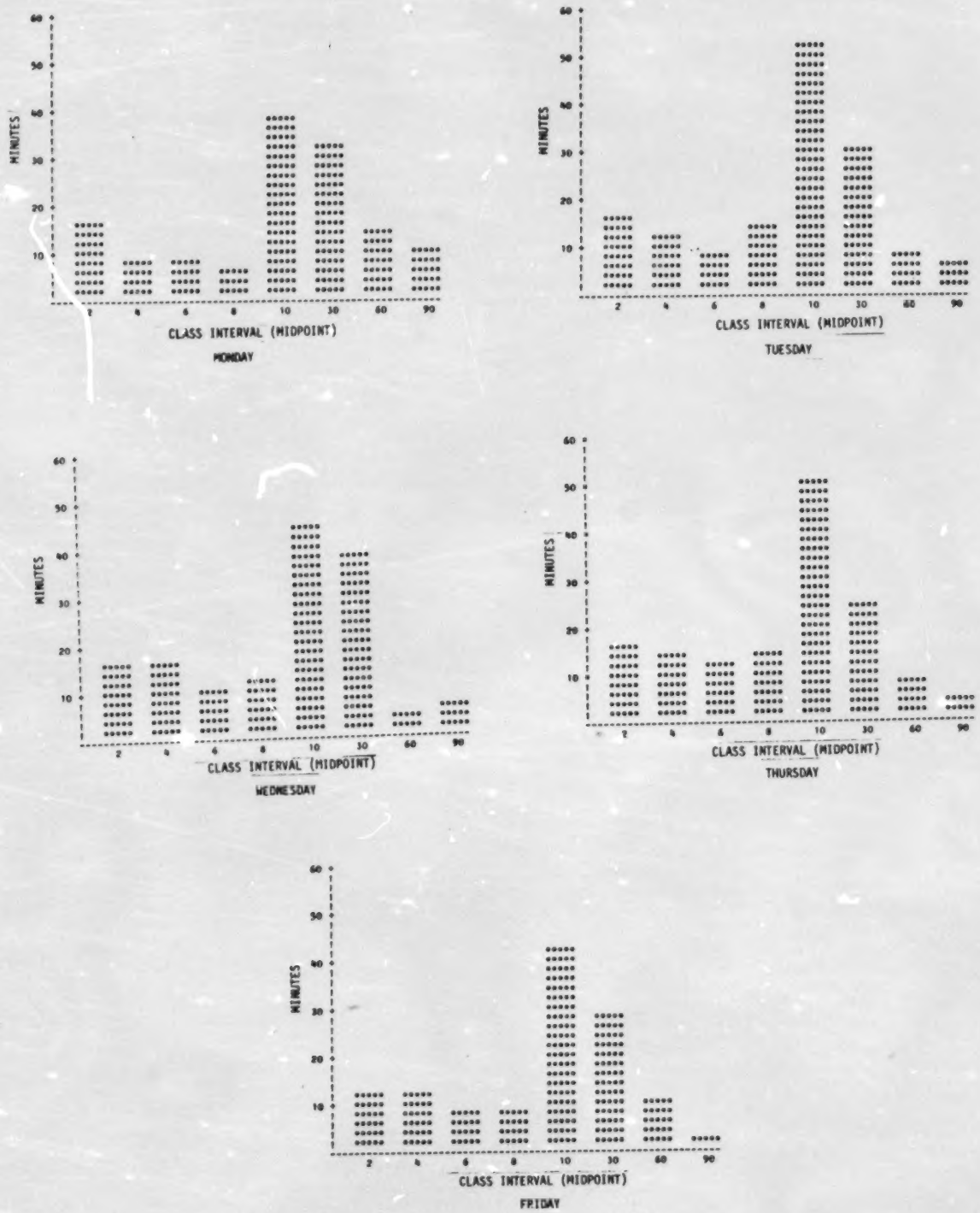


Figure A-5. Histogram of Mean Downtime by Day of Week

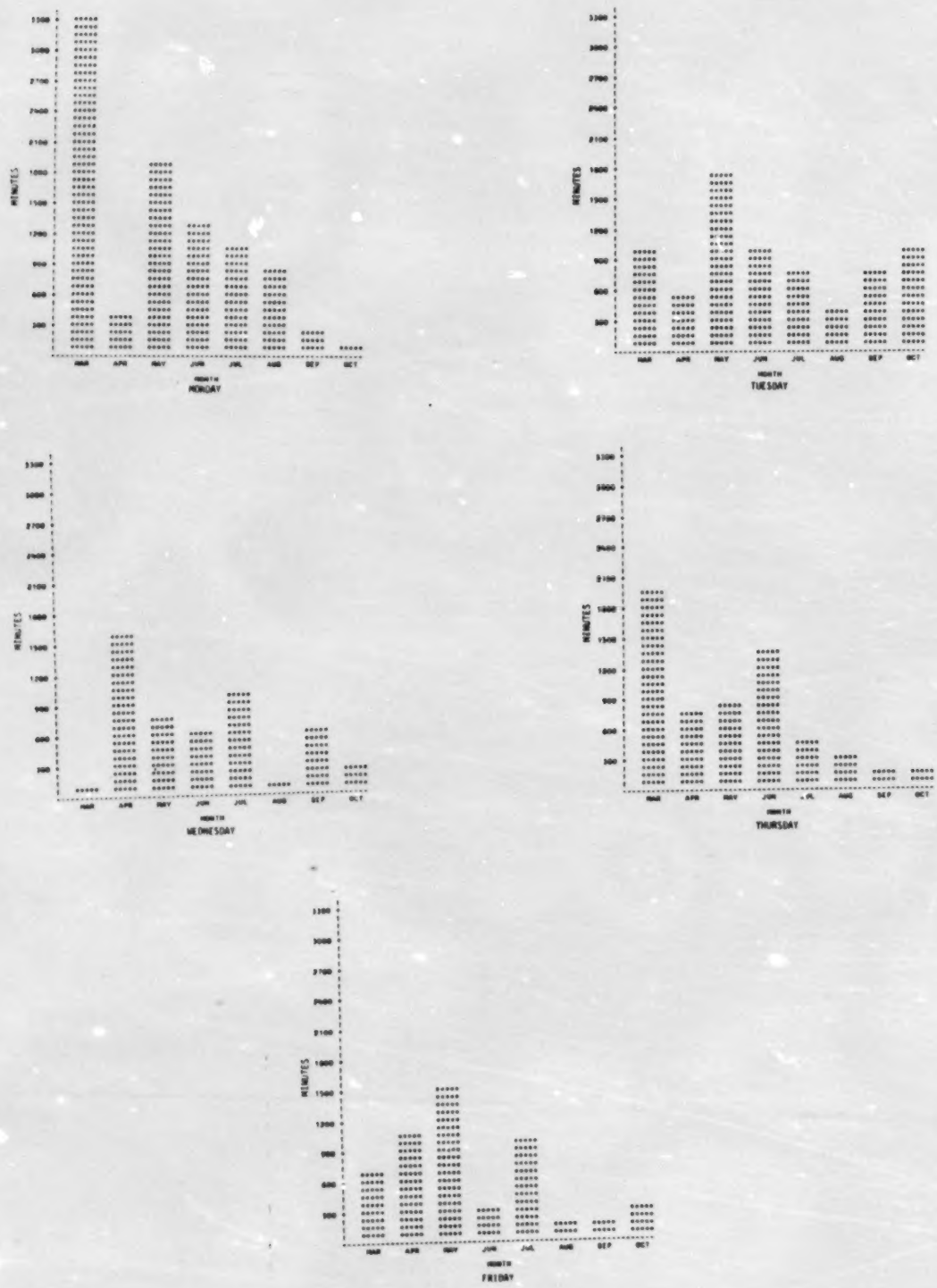


Figure A-6. Total Time System Reported Down for Each Day of Week

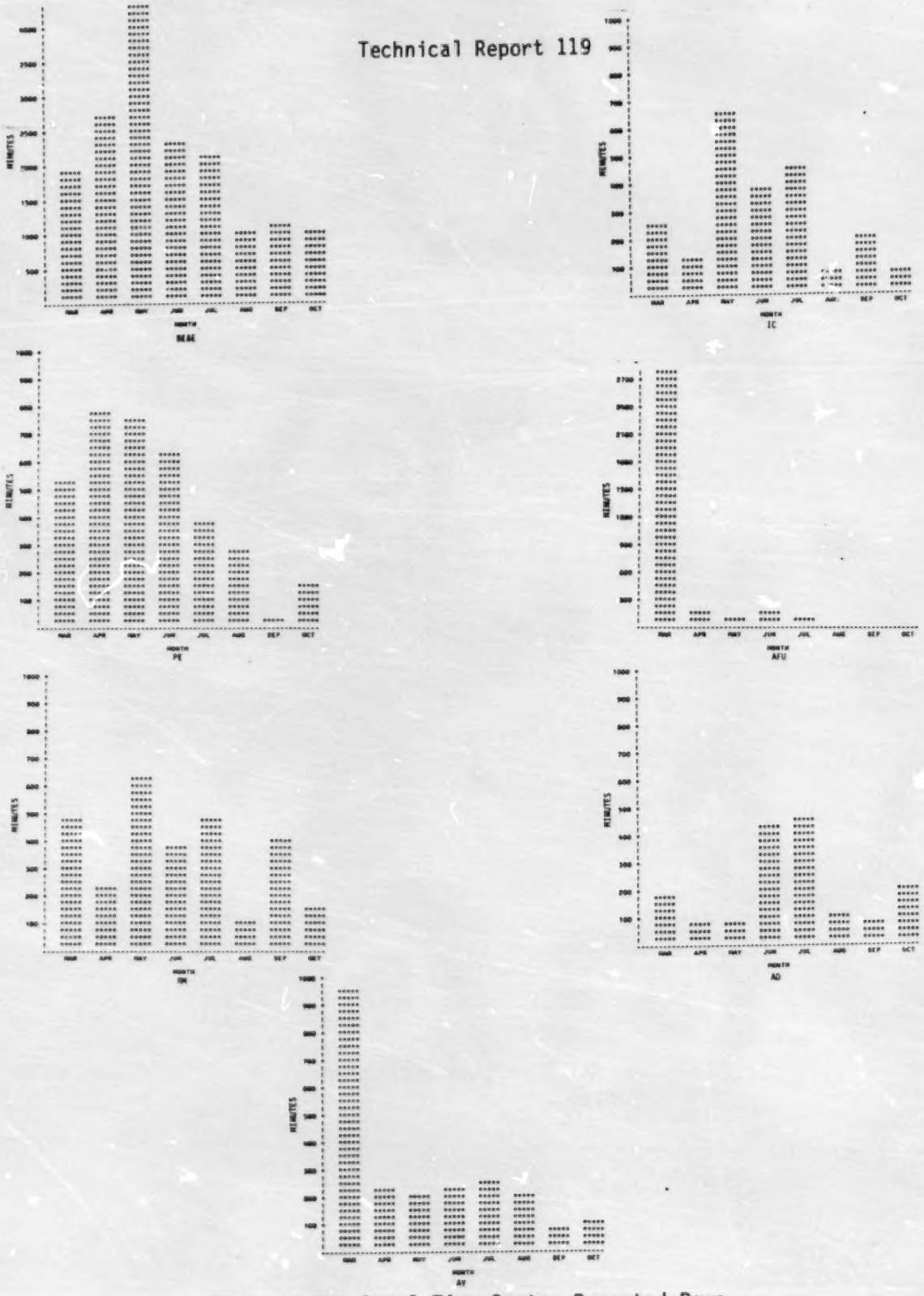


Figure A-7. Total Time System Reported Down for Each Course

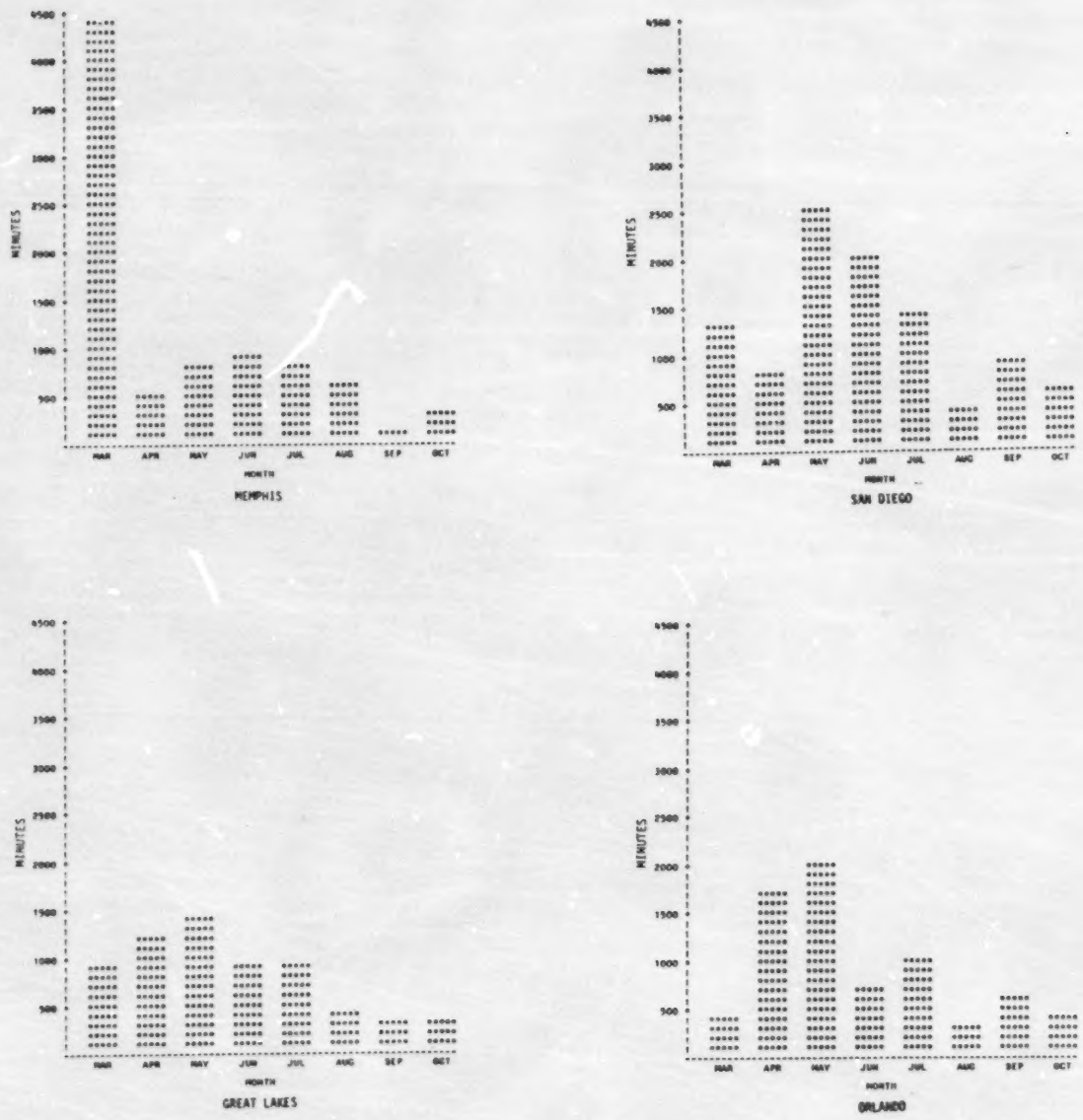


Figure A-8. Total Time System Reported Down for Each Location

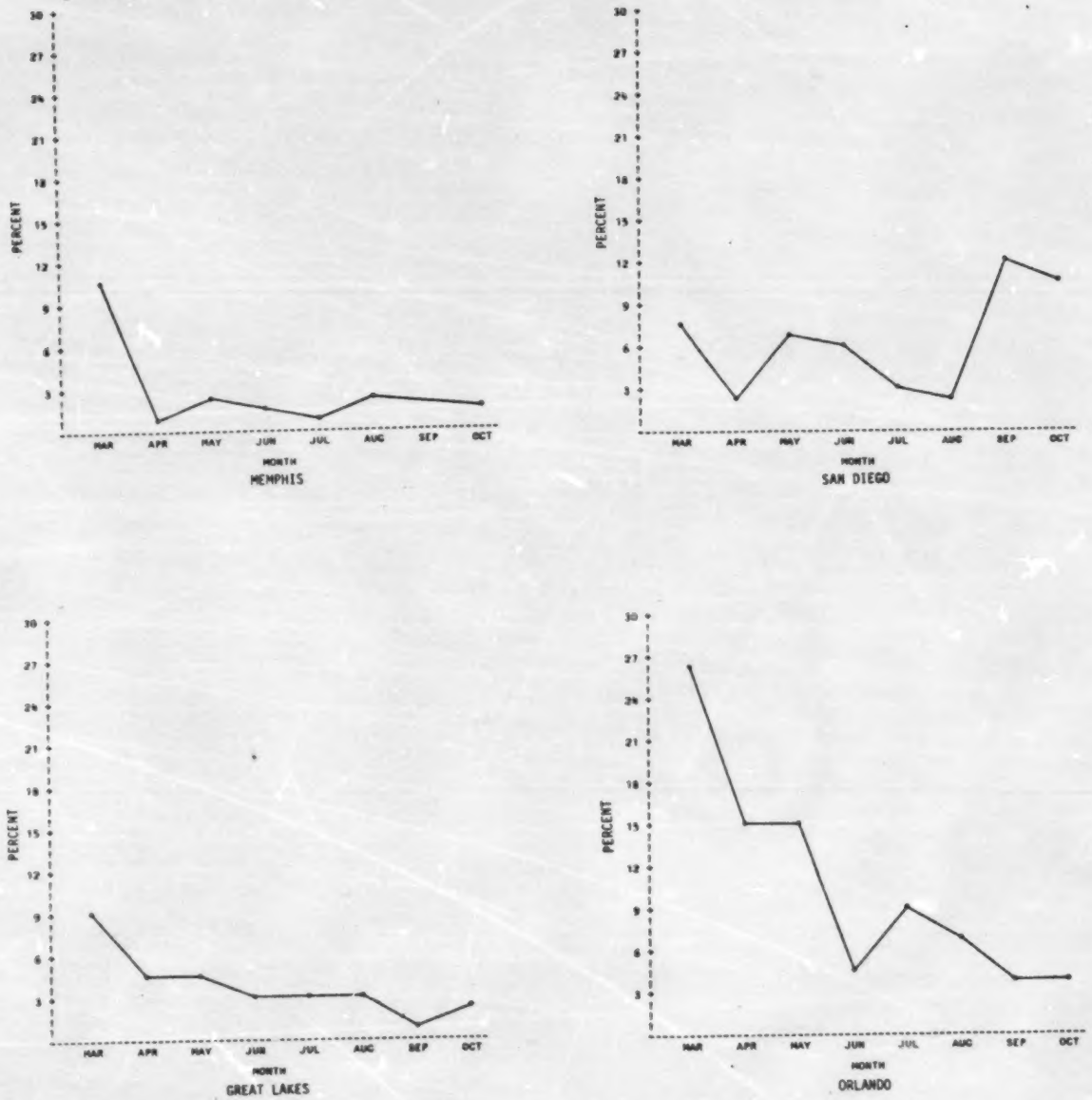


Figure A-9. Mean Percentage of Time System Not Available at Each Location

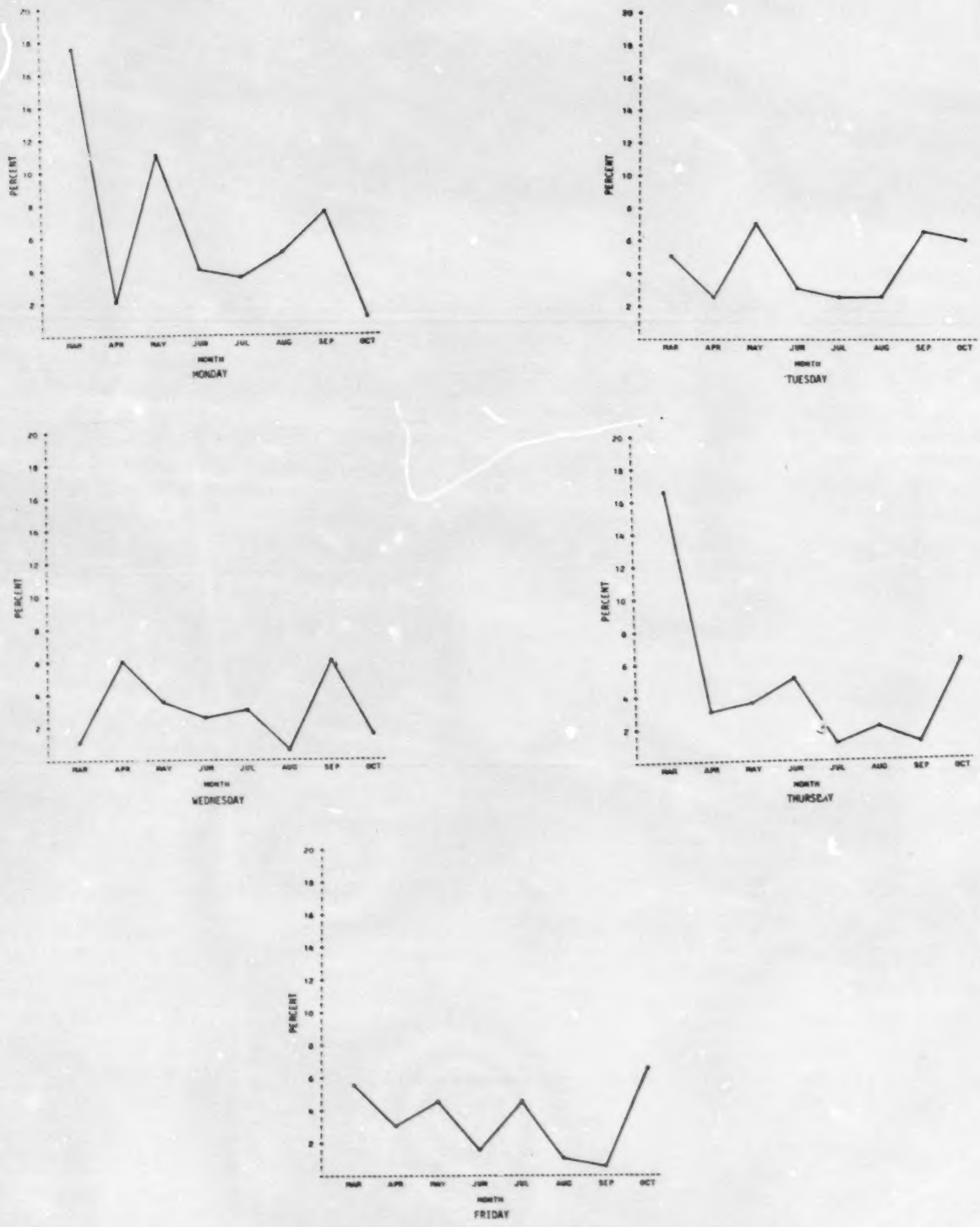


Figure A-10. Mean Percentage of Time System Not Available by Day of Week